A

PROJECT

FOR

CANALS

OF

IRRIGATION AND NAVIGATION

FROM THE

RIVER SOANE

IN

SOUTH BEHAR;

WITH

PLANS AND ESTIMATES.

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REPORT OF 1861.

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[*In a separate case*]

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SOANE CANAL PROJECT.

REPORT OF 1861

ON THE

SOANE CANAL PROJECT.

SECTION I. INTRODUCTORY.

THE first step towards the project contained in the following pages was the submission to Government, in 1853, of a Memorandum, printed in the Appendix, on the advantages to be derived from the construction, by Government, of Irrigation Works even in the permanently settled districts* of the Lieutenant Governorship of

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* As this paper may possibly fall into the hands of Engineers in England I may as well explain that in the North-Western Provinces the Government, as landlord, settles with the village communities once in 20 or 30 years, the amount of the annual rent of the land. When Government Irrigation Works are constructed, a price is fixed for the water, which is comparatively low, and a further profit is looked for from the enhancement of the rent of the land at the next settlement. In most of the districts of the Lieutenant Governorship of Bengal, the rent was settled in perpetuity at the end of the last century. Under that arrangement the total return for the outlay on Irrigation Works must be looked for in the price to be paid by the cultivators for the water. It was a common belief in Bengal that no such price could be obtained as would remunerate the constructors of the works; and hence much of my first report will be found devoted to establish the point that there is no doubt of a good return for the outlay even under the permanent settlement.

In the Madras Presidency there is no separate charge for the water supplied by the Government Irrigation Works, but the Government revenue is assessed at different rates for irrigated and unirrigated lands, and so the profit from Works of Irrigation appears entirely in the enhanced land revenue.

There is another difference between Works of Irrigation constructed in the Madras and Bengal Presidencies which, in order to avoid misapprehension, it may be well to notice here. (See the Index Map of India, Plate I.) The season for rice cultivation throughout India may be considered to be from June to November. The

Bengal, and especially of utilizing in that way the large quantity of water which flows uselessly into the Ganges in the floods of the Kurumnassa and Doorgowtee. I had not then seen the Soane, and had heard no accounts of it to lead me to look to it as a source from which to supply canals with water.

In the end of 1854, I was authorized to proceed to Shahabad and examine the country in detail. I remained there till April 1855, and after my return to Calcutta I submitted the report which will also be found in the Appendix. It will be seen that the quantity of water passing down the Soane in the dry season, and the favourable levels, made that river the main source of supply for irrigation for Shahabad, and suggested the probability of its also being the best source from which to irrigate the part of the District of Behar on its right bank; and the reservoir scheme became of secondary importance.

A detailed survey was ordered in December 1855. I was myself detained on duty in Calcutta, but two Officers—

Captain H. Farrington, 2nd Bengal Fusiliers,
(since, I regret to say, deceased,)

and Lieutenant H. E. Whish, 26th Bengal Native Infantry,
(now Executive Engineer, Etawa Division Ganges Canal,)

were placed under my orders to carry on the survey. It was February 1855 before they could get to work, but the survey was carried

south-west monsoon (which in the open ocean blows nearly due west) sets in early in May, and by the 20th June the air becomes so charged with moisture as to produce the rainy season which continues till September or October. But the monsoon is entirely deprived of moisture by the high lands of the interior before it reaches the Madras Coast, which in the rice-cultivating season is therefore for the most part totally destitute of rain. The rivers however are fed by the monsoon in their upper reaches on the high lands of the interior, and when irrigating canals are established on them, they supply the place of the rains which in the lower lands are absolutely wanting. On the change of the monsoon to the north-east the Madras Coast receives rain in November and December, which is of use to close but not to begin the cultivation.

In the Bengal Presidency the state of the seasons is quite different. The south-west monsoon curves round Cape Comorin and sweeps up the Bay of Bengal nearly as a due south wind. The rainy season sets in with full force in June, and

over the country to the east of the Soane to an extent to prove the practicability of using the water of the river for irrigation on the right as well as on the left bank.

In the end of 1855, I submitted estimates for carrying out a portion of the works on the west of the Soane, but the restrictions which were placed on Public Works expenditure at that time prevented their being sanctioned, and the complete project was awaited.

In June 1856, I was again enabled to visit the districts for a few months, and also in the early part of 1857, but was obliged to return to Calcutta in March. During the dry season of 1856-57 the detailed surveys were proceeded with, both on the right and left banks, to the extent shown in Plate III. The Mutiny took place in May 1857, and it soon became necessary to break up the establishment. Shahabad indeed was amongst the most disturbed districts.

I continued, however, to work up the materials which had been collected for the completion of the project, as my other duties would permit, until December 1860, when I was authorized again to visit the district and devote my whole time to the completion of the project, as far as the data collected would allow.

The project for the Soane Canals has thus been brought to maturity so far as to admit of its being submitted as a whole for the orders of Government.

It is not however by any means complete in detail, nor is it necessary that it should be. It would be a waste of labour to enter into all the details of levels and estimates of a scheme which may not be carried out for years, and which even if begun upon at once, could only be completed gradually, when ample time would

in ordinary seasons the rice can be cultivated without assistance from artificial irrigation. Therefore it must not be expected that the water will ordinarily be paid for in the Bengal Presidency at the same price as in Madras.

The Province of Orissa receives the benefit of the South-West monsoon like the rest of the Bengal Presidency. (See tract colored yellow on Plate I). The division between the part of the coast which does, and the part which does not receive the benefit of the rains with the South-West monsoon is I believe about half way between the mouths of Mahanuddee and Godavery.

be allowed to prepare complete estimates for each branch as they might be wanted. The project now submitted will be found, I believe, as far matured as any similar project has been before receiving the sanction of Government.

One principal point in which detailed information is wanting is the delineation of the local drainage. This has been nearly completed for the portion of the canals south of the Grand Trunk Road—that in fact contained in Plate IV. Some details of information have been collected north of the Trunk Road along the lines of which the levels have been taken, which will be given in their proper place; but a complete survey is wanting, and the lines levelled will need some revision of lining out (as will be apparent by consulting the Sections in Plates V. and VI.), but which the Officers employed were unable to rectify before the mutinies put a stop to their labours. Lieutenant Whish superintended the levels, &c., for the first 14 miles of the Western and for all that was done on the Eastern Soane Canal line. The rest of the work of 1857 is Captain Farrington's. The levels of the lines marked as "of 1861" are my own.

One of the most important points connected with the details of drainage is the direction and amount of the Soane floods which cross the country right and left in the last few miles of the course of the river. It will probably be best only to cross them with small channels for the irrigation, and to let the main navigable canals terminate in the Banās and Poonpoon clear of the floods of the Soane, instead of adopting the lines originally sketched out and levelled.

Another principal point on which details are wanting is as to the sub-soil, especially of the bed of the Soane, where the Dam is proposed to be placed. For this work in the estimate, the foundation is assumed to rest on sand of a very great depth, and it will probably be found to do so for the greater part of the width of the river. For the other works I have allowed an abundant proportion in the estimates to have under-sunk blocks in the foundations. The want of detailed information as to the soil is therefore, I hope, not likely to lead to the estimate being found insufficient.

Section II.—The Soane.

This river rises along with the Nerbudda and Mahanuddee on the elevated plateau of Central India near Ummurkuntuk, and runs 325 miles through a high rocky tract, receiving tributaries only from the south. On the north, the drainage area of the river is limited by the steep slopes and precipices of the Kymore range, along which the river runs, and the table-land above which drains away from the Soane to the Ganges. After quitting the elevated rocky region of Central India, the Soane enters the valley of the Ganges, and by a straight course of 100 miles, through the plains of South Behar, joins the sacred river between Arrah and Patna.

It is with this latter portion of the course of the Soane that the present project is concerned. In it the chief peculiarity of the river is its great width. Opposite Tilothoo (Plate II.) it attains a width of nearly three miles, and for the greater part of the 100 miles it is more than two miles wide. This immense bed consists of sand, and during 8 months of the year contains a stream of only a quarter of a mile wide, so that it appears to the traveller like a sandy desert. The depth of this wide channel is on the average under 20 feet, and in its deepest parts hardly exceeds 30. The strong dry westerly winds, which prevail from January to April and sometimes till June, heap up the sand on many parts of the eastern bank to 12 or 14 feet above the level of the country, with a sharp descent upon it at the angle of repose of the material, thus forming a natural embankment for many miles.

The drainage area of the Soane is (see Plate I.) nearly 23,000 square miles. Its extreme discharge in floods is about 1¾ million cubic feet per second, which, continued for 24 hours, would be equal to a drainage of 2¾ inches from the whole surface in that time. The heavy floods however are of but short duration, hardly ever exceeding four days; and the river even in the rainy season seldom fills its channel. In the dry season the lowest discharge is usually about 4,000 cubic feet per second. It is on this latter discharge that the present project depends.

During the present year the discharge of the Soane has been lower than I have ever known it before. This is the natural effect

of the deficiency of rain which produced the famine in the N. W. P. In the end of February the discharge was 3,500 cubic feet per second, and by the end of May it had fallen to 950 cubic feet per second. On the 24th May 1859 it was upwards of 4,000 cubic feet per second.

A discharge of only 950 cubic feet per second in the irrigating season, even if it were only an occasional occurrence, would require a total modification of the present project. But as the irrigating season in Shahabad and Behar terminates in the middle of March, and the river carried 3,500 cubic feet a second up to the end of February, it may be concluded that even in an unusually dry year there will still be an available supply of 3,000 cubic feet a second during the irrigating season.

The object is to throw this supply of water up upon the plains of Behar for the irrigation of the crops, and at the same time to afford a secure and certain means of navigation by canals, instead of the present almost impracticable navigation of the shallow stream that now meanders through the sandy bed of the river in the dry season, or the violent and uncertain flood which rushes down to the Ganges in the rains. The project is therefore principally for constructing artificial rivers like the canals of Northern India, of the Madras Presidency, and of Northern Italy; and only to a comparatively small extent still-water canals, such as are usual in England. The general arrangement proposed may be seen in Plate III.

The facilities which the Soane offers for our purpose are in some respects very great. It receives no tributaries of any considerable size from the point where it enters the plains to the end of its course, and absolutely none from the Trunk Road northwards. There is therefore no very formidable drainage to be crossed by the canals. It has a rapid descent—which is shared by the plains through which it runs—of not less than 2 and generally nearly 3 feet in the mile. There is therefore a complete command of level for the canals in a direction parallel to the river. But further the river (doubtless from having raised the plains by the deposits of its own floods) runs on the crest of the water shed, and so gives a command of level not only parallel but perpendicular to itself, as far as the Doorgowtee and Kurumnassa on the west, and the

Poonpoon on the east. This fall of the country, however, though advantageous in kind is excessive in degree; and though it will give great efficiency to the canals as machines for irrigating, it will make them expensive from the number of falls and locks that will be required.

Another drawback is the great width of the Soane, which renders the construction of a dam across it a very formidable undertaking.

There are further difficulties connected with the floods of the river. Although its banks are free from flood for 60 miles of its course, it still inundates the country in places in the last 20 miles of its west and 35 miles of its east banks, and very severely in the last 10 and 25 miles west and east respectively.

An interesting subject of inquiry connected with the Soane is the existence of ancient beds of the river in various parts. Some of them are apparently not very old, and yet the present banks of the river seem to be remarkably stable. One has already been mentioned as extending from Sydabad to near Patna. This is mentioned in Dr. Francis Buchanan's Report published as "Eastern India" by Montgomery Martin.

Another, indicated by a depression, and Soane pebbles in the wells, with a ridge of sand to the east is observable between Shumsherenugur and Wuleedad, and especially at the latter place (50th mile of canal line). Here Lieutenant Whish found traditions of the floods having, within the memory of man, penetrated the country in great bulk and strength. The last floods seem to have passed in near Mohummedpoor, at Rampoor Wyna and Umra (north of Wuleedad) and passed out again at Rampoor Wyna. The floods extended to Pepra and Budrabad (54th mile of canal line). This is reported not to have occurred for many years.

Another old channel is more obscurely indicated from Telcup (the canal head of 1861) on the west bank to the west of Sewahee, it may pass thence east of the Gonyla Hill, and cross the trunk road a mile east of the Kao. Possibly it may rejoin the present channel at the depression at Umeawur near Nasreegunj.

The following Table gives further details of the width and discharge of the Soane, and explains the cause of the flooding in the lower reaches of the river:—

Table of the dimensions of the Channel and flood discharge of the Soane River.

Number of Stations.	Names of Places.	Distance in Miles. Below first Station.	Distance in Miles. Below previous Station.	Low water level in feet above the Sea.	Fall per mile in feet $= f$.	Highest flood rise taken as d.	Mean velocity $v = \frac{9}{10} \sqrt{2 f d}$ in feet per second.	Width of river in feet $= w$.	$W d v =$ discharge in cubic feet per second.	
1	Mouth of Tenta.	0	0	492						
2	Baudoo	13	13	447	3·3	25	11·6	5,921	1,717,090	
3	Telcup	26	13	403	3·0	18½	9·4	9,682	1,683,700	
4	Dehree	43	17	355	2·7	16	8·4	12,8[illegible]	1,737,400	
5	Daoodnugur ..	59	16	315	2·5	19	8·8	10,423	1,732,725	
6	Behta	70	11	278½	3·3	22	10·8	7,470	1,771,872	
7	Urwul	81	11	253	2·3	22	9·1	8,504	1,702,501	
8	Mussowra	90	9	234½	2·0	21	8·2	9,820	1,691,004	
9	Koelwur	106	16	207	1·7	25 ?*	8·3	4,000 ?	830,000	No Section, but the Railway Bridge gives this width.
10	Mouth in Ganges.	118	12	183						

Assuming that for wide sandy beds like that of the Soane the mean depth in flood (allowing for the motion of the sand) is equal to the flood rise, it thus appears that the extreme flood discharge of the Soane is about 1,700,000 cubic feet per second; and that upon such occasions (of extreme flood) half of the water must be thrown over the country below Mussowra.

Section III.—Remarks on Climate.

In their Despatch, copied at page xxxvii. of the Appendices, the late Hon'ble Court remark "that the Provinces of Behar and Benares are the most favored of any portion of India in their ex-

* The E. I. Railway Engineers have observed no higher rise than 20 feet since 1853, when the Soane Bridge works were commenced.

emption from the calamities of drought on the one hand, and of excessive inundation on the other, and we think therefore that other parts of our territories claim your attention for works of this character more urgently than the Behar Districts."

In this remark of the Court's there seems to be some confusion between the portions of the provinces referred to north and south of the Ganges. North of the Ganges the Court's remark is no doubt just; but to the south the case is very different. Most of the country near the hills is dry and barren, while no tract in India is more subject to severe floods than the country between Patna and Jehanabad, from the lower portion of the Poonpoon eastward. Other parts of the districts also suffer from floods.

It is true that South Behar did not suffer more than a scarcity during the famines of 1837-38 and 1860-61, and that we have no record of the Province having suffered from famine later than the year 1783, on which occasion the Government of that day resolved upon the strange expedient of constructing a series of large granaries as a means of mitigating the severity of such visitations, if not of preventing them. Patna was the place selected for the first granary, and is the only place where one has been erected. It is a bee-hive shaped brick building of about 90 feet high with a winding staircase to the top, up which Jung Bahadoor once rode his hill pony. It is almost needless to say that the building has never been used. I have not been able to trace the steps by which the Resolution of the Government was abandoned. The building bears the following inscription in testimony that Behar is not always exempt from famine:—

No. 1.

IN PART OF A GENERAL PLAN

ORDERED BY THE GOVERNOR GENERAL IN COUNCIL,

20th of January 1784,

FOR THE PERPETUAL PREVENTION OF FAMINE

IN THESE PROVINCES,

THIS GRANARY

WAS ERECTED BY CAPTAIN JOHN GARSTIN, ENGINEERS,

completed on the 20th of July 1786,

FIRST FILLED AND PUBLICKLY CLOSED BY

[a blank is left on the stone.]

But though there is no record of any severe famine in Behar in recent times, there has not unfrequently been distress from scarcity of food. The most severe case of the kind that I have traced occurred in the years 1843 and 1844 from a failure of the rains of 1843. The fall in that year from June to October inclusive was in

Shahabad	21·3 inches.
Behar	18·9 "
Patna	19·6 "

In the previous year Patna had nearly 50 inches. The usual fall in the three districts is about 35 inches in the same period. The Superintendent of the Survey in February 1844 wrote thus:—"A large quantity of land is out of cultivation and cannot, I imagine, be sown now. The crops which are on the ground are also poor, and the unfortunate ryots are in many places in a wretched state. I saw some 20 individuals near Bheeta [Behta], opposite to Daoodnugger, where the crops are certainly not the worst, picking up the grain that had fallen in cutting the crops, kernel by kernel, for a subsistence." There was in fact an almost total failure of the rice crop followed by a bad cold weather crop. It was only a seasonable fall of rain in February that prevented the failure of the cold season crop also. The district rice had totally disappeared from the markets, and was replaced at a higher cost by rice from Bengal proper.

It is true that irrigation is not so much wanted in South Behar as on the east coast of the Madras Presidency, where the rains are totally wanting at the season for cultivating rice. It is also true that irrigation is not so much required in South Behar as in the Punjab and N. W. Provinces where the rains are more scanty and irregular. But it is not the less certain that irrigation is much wanted in South Behar, and that there exist means of affording it which many other provinces do not possess.

I do not imagine however that the late Court of Directors intended to discourage the establishment of irrigation canals in Shahabad and Behar, merely because there are other parts of India (often not possessing the means of constructing such works) which are more subject to drought. It was only to guard against the possibility of such other districts being overlooked that it was

desired by the Court to have a complete review (as since established in the Budget System) of the wants and means of supplying the wants of all the territories, before sanctioning the outlay of any large sums upon such works.

Section IV.—Situation of the Head of Supply.

The choice of a position for the Dam and Head works is the first point to be considered in establishing the canals. At first after examining in detail only the west side of the Soane, I was disposed to adopt the narrow part of the river between Bandoo and Khabra, just below the junction of the Koel. (See Section in Plate IV.) The Dam would have been shorter there than anywhere else, and there would have been an ample command of level. The numerous small drainage channels on the west, with the Hoosenee river and Telcup nala, could be passed without much difficulty. But there were three objections which proved stronger than the advantages of a short Dam and a good command of level. *First*, the junction of the Koel, and narrowness of the Soane at Bandoo produce a very high flood rise compared with what takes place on other parts of this river—about 26 or 27 feet above the low water. *Second*, the streams to be crossed on the left bank between Khabra and Putthurghatta are numerous and formidable. *Third*, there is a great deal of rocky soil between Deoree and Boodhwa, and again between Putthurghatta and Dhoondhooa. The extremely heavy rock-cutting near Deoree might have been avoided by taking the canal along a low ledge of rocks close to the Soane bank, walling it off from the floods, as was suggested by Lieutenant Whish; but on the whole these three objections were sufficient to induce me to abandon the idea of forming the head at Bandoo. To these may also be added the objection which occurred to Sir A. Cotton, that the small area of irrigation which would be obtained by the additional command of level would not meet the additional cost of the increased length of the canal.

My choice has therefore now fallen upon a site between Telcup and Jhikutteea for the Dam and Head-works. The river here is narrower than at any other place between Bandoo and the Grand Trunk Road, being 9,682 feet wide. There is abundance of rock

within a short distance on both sides of the Soane to afford the materials for the construction of the dam, and all the formidable drainage on the east with a great deal of that on the west is avoided. In fact, the site near Bandoo being abandoned, there is scarcely any other site open to selection than the one in the neighbourhood of Putthurghatta.

A Sketch Survey of the ground, with lines of levels plotted thereon, and a Section of the river, will be found in Plate VII.

The site however has its inconveniences. On the west side the land on the river bank is below flood level by perhaps 6½ feet on the edge of the bank, and the water reaches to a distance of upwards of 1,000 yards in land. The soil is apparently a moderately stiff clay as far down the bank as can be seen,—about 2 feet below the low water level. But I fear this stratum will not be found to extend further; for a well near the Abkaree (see Plate VII.), of 25 feet deep, reaches the sand and shingle of the Soane. The level of the ground there is about 373 feet above the datum of the levels, which brings the level of the water to about the level of the Soane. There seems to be no doubt therefore that on the west side we shall have to under-sink the foundations of the Head-works.

The bank does suffer to some extent from erosion by the Soane. I saw masses of the clay that had fallen into the river below the bank, and was told by the villagers that it sometimes fell in when a strong east wind occurred simultaneously with a high flood. The erosion must however be very small, as I could detect no unmistakeable difference between the position of the bank in the plot of our levelling operations on a scale of 4 miles to an inch compared with the Revenue Survey Village maps constructed on the same scale in 1846. It will be necessary however to provide some protection for the bank under the increased scour which will be caused by the canal Dam.

On the east side the inconvenience is of precisely the reverse kind. It consists in the existence of rock, and the possibility of having to excavate the canal channel in rock for a distance of about 4,000 feet. The excavation however will furnish part of the material for the Dam across the Soane, and will therefore be rather a source of inconvenience than of expense. It is impossible to say

what extent of rock-cutting will be necessary until the ground is opened. No trace of the rock is seen upon the surface in the line selected for the canal after crossing the Dhoondhooa nala; nor indeed for some hundreds of feet before coming to it—the last outcrop of rock is nearer the Soane as marked on the Survey, Plate VII.

SECTION V.—GENERAL PLAN OF THE CANALS.

The general plan of the Soane Canals now proposed is much the same as I proposed in 1855, but with the addition of canals on the east of the Soane for the irrigation of a portion of the Behar and Patna Districts. The main features of the proposal are the fan-like spread of irrigation channels from 10 or 12 miles below the Head-works all over the country right and left of the Soane as far as the Kurumnassa and Ganges on the west and north, and the Morhur and Poonpoon on the east; and the provision of four main lines of navigation, to Benares, to the mouth of the Kurumnassa, to Arrah and to Patna. It is not intended that all these should be constructed at first, nor, perhaps, at all. But it is desirable to estimate for all, in order to facilitate selection. The details of the scheme will best be gathered from Plate III. and the following Tables:—

Table of the Western Soane Canal and its Branches.

		Supply of water required.						Channel.			
		Irrigation.									
		Areas.	Square Miles.	Cubic feet per second.	Navigation. Cubic feet per second.	Supply to other branches. Cubic feet per second.	Total cubic feet per second.	Width at bottom in feet.	Depth of water in feet.	Fall of the bed per mile in feet.	Length in miles.
A	Main Canal	$\frac{10\times3}{2}$	15	12	...	B+L=1,968	1,980	73	7·5	0·75	$10\frac{1}{2}$
B	Arrah Branch above Ranipoor branch head	$(3\times2+16\times5+21\times10)\times\frac{1}{2}$	148	111	...	C+J=766	877	$42\frac{1}{2}$	5·5	1·04	22
C	Ditto below ditto and above the Peeroo branch head	7×5	35	27	...	D+G=549	576	31	4·62	1·25	7
D	Ditto below Peeroo and above the Nansagor branch head ...	$16\frac{1}{2}\times7\frac{1}{2}\times\frac{1}{2}$	62	47	...	E+F=288	335	23	3·75	1·54	$15\frac{1}{2}$
E	Ditto to terminus	$17\times7\frac{1}{4}$	123	93	150	......	243	$18\frac{1}{2}$	3.25	1·75	$20\frac{1}{2}$
F	Nansagor branch	$17\times3\frac{1}{2}$	60	45	...	......	45	8	1·75	2·00	$22\frac{1}{2}$
G	Peeroo branch above Jugdispoor branch head	$\frac{1}{2}(14\times6\frac{1}{2}+10\frac{1}{2}\times3\frac{1}{2})+\frac{6\frac{1}{2}+4\frac{1}{2}}{2}\times2\frac{1}{2}$	77	57	...	H+I=157	214	17	3·1	1·80	$11\frac{1}{2}$
H	Ditto below ditto	$17\times6\frac{1}{2}$	110	84	...	......	84	11	2·3	2·00	$17\frac{1}{2}$
I	Jugdispoor branch	$15\times6\frac{1}{2}$	97	73	...	......	73	$10\frac{1}{2}$	2·2	2·00	17

J	Ranipoor branch above escape..	$\frac{1}{2}(17\frac{1}{2}\times7\frac{1}{2}+10\times6\frac{1}{4}+7\frac{1}{2}\times4\frac{1}{4}$	111	84	...	L=106	190	16	3	1·90	22
K	Ditto below ditto	$\frac{1}{2}(29\times14\frac{1}{4}-17\frac{1}{2}\times7\frac{1}{2})$	141	106	...	.. ...	106	$12\frac{3}{4}$	2·6	2·00	$13\frac{1}{2}$
L	Sasseram branch above the trifurcation	$3\frac{1}{2}\times4+\frac{1}{2}\times1\frac{1}{2}\times3$	16	12	...	M+O+Q=1,079	1,091	49	6	1·00	7
M	Ditto below ditto and above the escape	$(2\times5+15\frac{1}{2}\times7+14\frac{1}{2}\times4)\frac{1}{2}$	88	66	150	N=72	288	20	3·5	1·64	22
N	Ditto to end	$20\times(3\frac{1}{2}+6)\times\frac{1}{2}$	95	72	...	......	72	$10\frac{1}{2}$	2·2	2·0	$18\frac{1}{2}$
O	Jugjeewan branch above escape	$5\times15\frac{1}{2}+\frac{1}{2}\times1\frac{1}{2}\times5$	$81\frac{1}{4}$	61	...	P=61	122	14	2·7	2·0	$17\frac{1}{2}$
P	Ditto below ditto	$5\times15\frac{1}{2}+\frac{1}{2}\times2\frac{1}{2}\times4$	$82\frac{1}{2}$	61	...	......	61	$9\frac{1}{2}$	2 1	2·0	15
Q	Buxar branch above Chowsa branch head	$4\frac{3}{4}\times6\frac{1}{2}+\frac{1}{2}\times6\frac{1}{2}\times3\frac{1}{2}$	42	31	...	R+W=638	669	37	4·7	1·18	8
R	Buxar branch below Chowsa and above Buradhee branch head	$7\times10\frac{1}{2}$	$73\frac{1}{2}$	55	...	S+V=188	243	$18\frac{1}{2}$	3 25	1·75	11
S	Ditto below Buradhee and above Doomraon branch head	$15\times(3+4\frac{1}{2})\frac{1}{2}$	56	42	...	T+U=98	140	$14\frac{1}{2}$	2·8	2·00	$11\frac{1}{2}$
T	Ditto to end	$3\frac{1}{2}\times11\times\frac{1}{2}+7\times11$	96	72	...	......	72	$10\frac{1}{2}$	2·2	2·0	18
U	Doomraon branch	$17\times4\frac{1}{4}\times\frac{1}{2}$	34	26	...	......	26	7	1·6	2·0	13
V	Buradhee branch	$6\frac{3}{4}\times8\frac{1}{2}+2\times3\frac{1}{2}$	64	48	...	.. .	48	$8\frac{3}{4}$	2·0	2·0	13
W	Chowsa branch above the Kochus branch head	$13\times6\frac{3}{4}\times\frac{1}{2}$	44	33	...	X+Z=362	395	26	4·1	1·40	$6\frac{1}{2}$
X	Ditto below ditto and above escape...	$\frac{1}{2}\times13\times8+2\times4\frac{1}{2}+7\times5\frac{1}{2}\times\frac{1}{2}$	$80\frac{1}{4}$	60	...	Y=254	314	21	3·6	1·60	$12\frac{1}{2}$
Y	Ditto to end	$14\frac{1}{2}\times9\frac{1}{2}$	138	104	150	......	254	$18\frac{1}{2}$	3·3	1·72	15
Z	Kochus branch...	$9\frac{1}{2}\times(10+3\frac{1}{2})\frac{1}{2}$	64	48	..	......	48	$8\frac{3}{4}$	2·0	2·0	13
		Total	2,033	...	...	......	...	...	...	...	361

Table of the Eastern Soane Canal and its Branches.

Distinguishing letters.	Name of Branches.	Supply of water required. Cubic feet per second. Irrigation. Areas.	Irrigation. Square Miles.	Irrigation. Cubic feet per second	Navigation.	For other branches.	Total.	Channel. Width at bottom in feet.	Channel. Depth of water in feet.	Channel. Fall of bed in feet per Mile.	Channel. Length in Miles.
a	Main Canal	$(5\times3)\times\frac{1}{2}$	$7\frac{1}{2}$	6	...	b+k=1,138	1,144	52	$6\frac{1}{8}$	0·94	12
b	Patna branch above Jakhowra branch head	$\frac{1}{2}(11\times6)$	33	25	...	c+g=713	738	$38\frac{1}{2}$	$5\frac{1}{8}$	1·11	8
c	Ditto below ditto and above Kojhassa branch head	$\frac{1}{2}(15\frac{1}{2}\times2\frac{1}{2}+15\frac{1}{2}\times7)$	74	55	...	d+h=604	659	$34\frac{1}{2}$	$4\frac{7}{8}$	1 18	14
d	Ditto below Kojhassa and above Paleegunj branch head... ...	$11\times3\frac{1}{2}+\frac{1}{2}(23\frac{1}{2}0\times9)$	144	108	..	e+i=424	532	$29\frac{1}{2}$	$4\frac{1}{2}$	1·25	27
e	Ditto below Paleegunj and above Dinapoor branch head	9×5	45	33	...	f+j=358	391	26	4	1·40	$9\frac{3}{4}$
f	Ditto to terminus	$25\times4\frac{1}{8}$	112	84	150	......	234	18	$3\frac{1}{4}$	1·78	27
g	Jakhowra branch	$16\frac{1}{2}\times3\frac{3}{4}+\frac{1}{2}(4\frac{1}{2}\times4)$	71	54	...	......	54	6	2	2·00	$24\frac{1}{2}$
h	Kojhassa branch	$78\times4\frac{1}{2}+(7\times4\frac{1}{2})\frac{1}{2}$	97	72	...	......	72	$10\frac{1}{2}$	$2\frac{1}{4}$	2·00	27
i	Paleegunj branch	9×5	45	33	...	......	33	7	$1\frac{1}{3}$	2·00	14

j	Dinapoor branch	$\frac{1}{2}(26\frac{1}{2} \times 8 + 26 \times 4\frac{1}{2})$	165	124	...	......	124	14	$2\frac{3}{4}$	2·00	20
k	Tikaree branch above Jummoor branch head	$2\frac{1}{2} \times 4\frac{1}{2} + \frac{1}{2} \times 9 \times 2\frac{1}{2} + 4 \times 4 \times \frac{1}{2}$	30	24	..	l+r=376	400	26	4	1·40	10
l	Ditto below Jummoor and above Khurona branch head	$2\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$	$4\frac{1}{2}$	3	...	m+s=358	361	23	$3\frac{3}{4}$	1·51	5
m	Ditto below Khurona and above Achore branch head	$11 \times 3\frac{1}{4} \times \frac{1}{2}$	18	13	...	n+t=274	287	20	$3\frac{1}{2}$	1·64	11
n	Ditto below Achore and above Dadur branch head	$4\frac{1}{2} \times 4 \times \frac{1}{2}$	9	7	...	o+u=252	259	$18\frac{1}{2}$	$3\frac{1}{4}$	1·74	8
o	Ditto below Dadur and above Hameednuggur branch head ...	$8\frac{1}{2} \times 6\frac{1}{2} \times \frac{1}{2}$	$27\frac{1}{2}$	21	...	p+v=198	219	17	$3\frac{1}{8}$	1·85	5
p	Ditto below Hameednuggur and above Kutangee branch head ...	$3 \times 3 + 3 + 2$	14	12	...	q+w=122	134	$14\frac{1}{2}$	$2\frac{3}{4}$	2·00	4
q	Ditto to terminus	17×5	85	64	...	......	64	10	$2\frac{1}{4}$	2·00	24
r	Jummoor branch...	$6 \times 3\frac{1}{2}$	21	15	...	......	15	5	$1\frac{1}{2}$	2·00	$6\frac{1}{2}$
s	Khurona branch	$9\frac{1}{2} \times 8 + 10\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$	$94\frac{1}{2}$	71	...	......	71	$10\frac{1}{4}$	$2\frac{1}{4}$	2·00	16
t	Achore branch	5×4	20	15	...	......	15	5	$1\frac{1}{4}$	2·00	$5\frac{1}{2}$
u	Dadur branch	$\frac{1}{2}(8\frac{1}{2} \times 9 + 4\frac{1}{2} \times 2\frac{1}{2})$	44	33	...	......	33	7	$1\frac{3}{4}$	2·00	12
v	Hameednuggur branch	$15\frac{1}{2} \times 11 \times \frac{1}{2}$	85	64	...	......	64	10	$2\frac{1}{4}$	2·00	$15\frac{1}{2}$
w	Kutangee branch	$17 \times 4\frac{1}{2}$	$76\frac{1}{2}$	58	...	......	58	$9\frac{1}{2}$	2	2·00	15
		Total.	$1,322\frac{1}{2}$	...	...	......	...	...	...	...	3 20

Table of the Lines of Canal for Navigation only, which may be added to the foregoing.

Names of Canals.	Length in Miles.	Width at bottom in feet.	Depth of water in feet.	Fall of bed per mile.	Discharge in cubic feet per second.	Remarks.
I. Navigable Canal parallel to the last portion of Patna Branch	27	20	3½	1 inch ...	63	The discharges of these canals will probably not exceed one-half of what is set down as the theoretical discharge, owing to growth of weeds, &c.
II. Navigable Canal parallel to the last portion of the Arrah Branch	20	20	3½	1 inch ...	63	
III. Navigable Canal parallel to the last portion of the Chowsa Branch ...	27	20	3½	1 inch ...	63	
IV. Navigable Canal parallel to the second portion of the Sasseram Branch ...	15	20	3½	1 inch ...	63	
V. Main Navigable Line to the Ganges, nearly opposite Benares	56	25	5	4 inches..	247	
Total ...	145					

The total length of the Canals is thus—

Western Soane Canals for Irrigation ...	...	361 Miles.
Eastern ditto ditto	...	320 "
Total	...	681 Miles.
Add Canals for Navigation only ...	...	145 "
Grand Total	...	826 Miles.

The total discharge is—

Western Canals ...	...	1,980 cubic feet per second.
Eastern ditto ...	...	1,144 " "
Total	...	3,124 cubic feet per second.

of which 600 cubic feet per second is reserved for navigation and 2,624 cubic feet per second proposed to be expended in irrigation.

It will be observed in the foregoing Tables that I have calculated the requirements of the districts for irrigation at ¾ths of a cubic foot of water per second for every square mile of gross area. This is rather a larger allowance than I calculated upon in para. 21 of my Report of 1855, where I mentioned ⅔rds of a cubic foot per square mile of gross area as probably a sufficient provision of water. Sir Proby Cautley allows 8 cubic feet to each mile of canal. If the canal be supposed to irrigate 4, 5 or 6 miles on *each* side, this gives 1, ⅘ths or ⅔rds of a cubic foot per square mile of gross area. I believe the allowance I have made will be found sufficient, and not greater than the cultivation will require.

It will further be observed that the slope of bed given to the canals is, for the larger lines, much less than it has been usual to allow in Northern India. I have in fact adopted a fixed velocity instead of a fixed slope of bed. The slope of bed is calculated to give the velocity of about 3 feet per second (2 miles an hour) with side slopes of 1½ to 1, and a width on floor equal to the depth plus one squared, in feet; and from these data and the required discharge, the dimensions of the channels are calculated. I have used the

formula of Eytelwein as given in Young's Tracts on Hydraulics, in these calculations, viz.:—

$$v = \tfrac{9}{10} \sqrt{2\,f\,d}.$$

where

v= velocity per second in feet.

f= fall of bed per mile in feet.

d= the hydraulic mean depth in feet.

For the navigable lines—that is, for the lines of canal where water is required for navigation in excess of what is passing down the canal for irrigation—I have allowed in each case 150 cubic feet per second. It will be observed that there are four such lines included in the Tables of irrigating canals. These, with the fall and velocity allowed, only have a width of 18½ feet at bottom and about 28 feet on the water line, and a depth of 3¼ feet of water. This size, though larger than that of many of the English canals for navigation, is undoubtedly small for a canal of any considerable traffic. This width and depth moreover is liable to be drawn upon for the irrigation to such an extent as might leave the width at water line 26¼ and the depth 2⅔ feet. The dimensions laid down by the French for a canal of "Petite Navigation" are 33·3 feet wide at the water line and 22 feet on the floor, with a depth of 5 feet of water. The depth is not necessary with an abundant supply of water, such as is given by the proximity of the irrigating canal, and the dimensions of my channels in other respects nearly reach those of the canals of Petite Navigation, which are larger than many English canals. Still I think these channels alone will not suffice for the traffic likely to be developed on the Soane Canals, and I have added in lines parallel, still-water canals of 20 feet width at bottom and 3½ feet deep, to take what would otherwise be the up-stream traffic of the flowing canals, whenever the latter are less in width than 22 feet on the floor.

For the navigable line to Benares, where the canal is a still-water one only, without a parallel running stream, I have allowed a width of 25 feet on the floor and 40 on the water line with 5 feet depth of water. This canal will be 56 miles long. Allowing

a waste of as much as 12 inches of surface per diem, and a loss of double the contents of the locks for the passage of each lock of boats, and supposing 50 locks full to pass daily, the supply required will be 137 cubic feet per second for the former, and 29 for the latter, or 166 cubic feet per second in all. The canal must have a slight slope, about 2 inches per mile, to carry the supply forward, and this will save some expense in locks; but it will be better to allow 4 inches, to make up for periods of low water, and the obstruction arising from the growth of weeds, &c. The flow can always be regulated by the stop boards of the waste channels of the locks. Mills may be established at the locks on the upper part of this canal without any danger of want of water for working them, and the locks (except for the descent into the Ganges) will all be on the upper part. I have only allowed 150 cubic feet per second for this canal, and the short line parallel to the navigable portion of the Sasseram branch; but this will, I think, fully suffice, considering that the Main Navigable line will have the benefit of the tail waters of the irrigation when not in full use. There would be no difficulty, however, in increasing the supply to any extent that is likely to be required. It would make no appreciable difference in the capacity of the large upper channels of the flowing canal.

In the flowing canals an escape is allowed at every bifurcation, and in some instances when the lines are long, at intermediate points. The dimensions of the channels are intended to be preserved without change until the occurrence of an escape gives the means of altering them without risk of inconvenience from surplus water.

With so great a variety of size of channel it would be a most laborious business to give estimates and designs in detail for bridges and other works exactly suited to each individual channel, and it would also probably be, after all, of no use; for it is hardly likely that the sizes of channels will be exactly adhered to when the works come to be laid out on the ground. What is now laid down represents the scheme as a whole and in its main features correctly, but it must be open to modification in detail to suit the facts that will be brought out in the detailed examination of the country that has yet to be undertaken.

I have therefore divided the channels into classes as follows :—

	Range of widths of canals at bottom.	Range of depths of water.	Range of discharges.	Range of fall per mile.
	Feet.	Feet.	Cubic feet per second.	
I ...	73	7·5	1,980	0·75
II ..	52–49	6⅛–6	1,144–1,091	0·94–1·00
III ...	42½–37	5½–5¼	877–738	1·04–1·11
IV ...	34½–29½	4⅞–4½	669–532	1·18–1·25
V ...	26–23	4¼–3¾	400–335	1·40–1·54
VI ...	21–17	3·6–3·1	314–214	1·60–1·80
VII ...	16–12¾	3–2·6	190–106	1·90–2·00
VIII ...	11–9½	2·3–2·25	84–64	2·00
IX ...	9–7	2–1·66	54–33	2·00
X ...	5–	1·25	15	2·00

The estimates for bridges and for the land to be taken up are made out for these classes, see Plates XVII. and XX. For the other works, designs have been drawn up only for some of the classes of channels, and the cost of the works for the others deduced from these, as will be observed when I come to speak of the several works.

One general remark must however be made here. I have drawn nearly all the designs for works with undersunk blocks in their foundations. This is not done with the idea that such foundations will be always, or even to any large extent required, but to enable me to show in the estimates what is likely to be the outside cost of each description of work. In the general estimates of the cost of the canals, I have assumed that half the works will require such foundations. This is a very liberal allowance, and more than covers any probable excess in actual cost over estimate arising from the soil being found unfavorable when the works are put in hand.

Section VI.—Land, Fencing, Roads, Plantations and Excavation.

Plate XX. shows the width of land to be taken up for each class of channel, for the canal and banks. The sections on which these widths are taken give more than the average depths of cutting, and by taking a little less where the cutting is light, and more where it is heavy, I think the widths of land will be ample.

These widths give the following areas:—

Deep cutting, West Main Canal, 660 feet wide, or 80 acres = 128 beegahs per mile, which at Rs. 6 per beegah (3,025 square yards), and with 10 per cent. added comes to Rs. 845 per mile.

Deep cutting, East Main Canal, 600 feet wide, or 72¾ acres = 116⅓ beegahs per mile, which at Rs. 6 per beegah, and with 10 per cent. added, comes to Rs. 768 per mile.

Ordinary 1st Class Channel, Western Main Canal, 440 feet wide, or 53⅓ acres = 85⅓ beegahs per mile, which, as above, comes to Rs. 563 per mile.

Channels, IInd Class, 330 feet wide, or 40 acres = 64 beegahs per mile, which, as above, comes to Rs. 422 per mile.

Channels, IIIrd Class, the same.

Channels, IVth Class, 220 feet wide, or 26⅔ acres = 42⅔ beegahs per mile, which, as above, comes to Rs. 282 per mile.

Channels, Vth Class, 200 feet wide, or 24 acres = 38⅔ beegahs per mile, which, as above, comes to Rs. 255.

Channels, VIth Class, 180 feet wide, or nearly 22 acres = 35 beegahs per mile, which, with 10 per cent. added, comes to Rs. 231 per mile.

Channels, VIIth Class, 150 feet wide, or 18¼ acres = 29 beegahs per mile, which, with 10 per cent. added, comes to Rs. 192 per mile.

Channels, VIIIth Class, 130 feet wide, or 14½ acres = 25¼ beegahs per mile, which, with 10 per cent. added, comes to Rs. 166 per mile.

Channels, IXth Class, 100 feet wide, or 12 acres = 19⅓ beegahs per mile, which, with 10 per cent. added, comes to Rs. 127½ per mile.

Channels, Xth Class, 80 feet wide, or 9½ acres = 15½ beegahs per mile, which, with 10 per cent. added, comes to Rs. 102 per mile.

Besides these spaces for the channel there will be required extra land for workshops and residences for the Canal Engineers and Subordinates, and for the Station Houses or Chokees, and for

the space between the lock channel and main canals in cases where the locks are placed on separate channels. This latter item will amount to 120 acres or 192 beegahs for each lock channel costing Rs. 1,152.

For residences for Engineers, Subordinates, and work-people, Workshops, quarries, and roads, a great deal of land will be required at the Canal Heads on both sides. There is abundance of uncultivated high open ground, and I think it would be best to take up at once an ample space, say of 300 acres (480 beegahs) on the west, and 200 (320 beegahs) on the east side of the Soane. The land would probably cost much less than the rate of Rs. 6 a beegah, which I have set it down at, agreeably to the average rate deduced in para. 53 of the Report of 1855 (Appendix A, page xxxii).

I propose also to allow smaller plots of ground for similar purposes at the places where the Head Quarters of Executive Engineers of Divisions are likely to be. These will probably be four in number, one for each of the main branches of the canals—possibly at Bullea or Behta for the Arrah branch, at Kurroundea for the Sasseram branch, at Daoodnuggur or Urwal for the Patna branch, and at the crossing of the Bootana for the Tikaree branch. I include 20 acres (32 beegahs) for this purpose in the estimates for the main trunks of each of these branches.

For the other purposes mentioned, the addition of 10 per cent. to the extent of land required for the canal and banks will suffice.

After possession of the land has been obtained, the first thing to be done will be to mark the boundaries by ditches, and to form roads of communication along the whole extent. Sums for this purpose are included in the Baree Doab Canal estimate, but none appear in that of the Ganges Canal. In Shahabad and Behar there is a great deficiency of good district roads, and the communication across country, during the rains, and even at other periods, is by no means easy. It will be a necessity to form the communication, and it is better to have it expressly provided for in the estimate than to charge it to excavation. The work will consist of removing jungle and obstacles, moderate raising here and there, temporary bridges, and the application of sand, and here and there a little metal to very bad swampy soils. I allow Rs. 400

a mile of the Main Canals, East and West, and of the Sasseram branch upper; Rs. 250 a mile to the other channels down to Class VI. inclusive, and Rs. 150 a mile for the rest.

As all the spoil banks and other spare land will be planted with trees, it will be necessary to commence nurseries of useful kinds of trees as soon as the land is taken up, and the cost of these nurseries must be provided for in the estimate for construction until the canal lines are brought into use, when this maintenance will fall naturally upon the working expenses. The estimates for the Baree Doab Canal lead me to think that a charge of one rupee per beegah of the land occupied will be a sufficient provision for the formation of nurseries; which will thus be an addition to the expense equal to one-sixth of the cost of the land. Care must of course be taken to select useful trees. The Mango and Sissoo should form the principal part of the plantations.

On the subject of the excavations I need say nothing in addition to the note to the Estimate No. 1 in the Appendix, except that no part of the light excavation should be begun till the deep cutting work is well advanced. To proceed otherwise would be to charge the works with interest on the outlay at an unnecessarily early period. It is also to be noted that the passage of the drainage from the roads and local depressions through the high banks of the deep cutting is intended to be by intervals left in the banks, and not by masonry drains. The drainage on the up stream side (when the canal crosses the drainage) should be conducted along the side of the spoil bank and passed into the inlets or other works intended for the reception of the main drainage of the country.

Section VII.—Accommodation for Engineers and Subordinates, Workshops, &c.

In the estimate for this project I have included quarters for the Engineers and European Subordinates and Clerks. In so doing I am supported by the opinion of Sir Proby Cautley; and it seems to me evident that it is in many respects objectionable to have Engineers and Subordinates engaged in building operations on their own account while employed on Government work. The outlay would of

course bring a return in the shape of rent to be deducted from the salaries of the occupants.

Of necessity the quarters must in the first instance be temporary, and it will probably be found economical to construct permanent quarters after a time in preference to renewing the temporary buildings. But this should not be done hastily: time should be allowed to make sure by experience that the situations selected are the most convenient. There would probably be changes of temporary quarters, for which provision must be made.

I suppose the Superintending Engineer to have two Assistant Engineers (one as a personal Assistant, and one for survey duties) and eight European Clerks. I also suppose the European Establishment for the execution of the works to consist of five Executive Engineers, 15 Assistant Engineers, 60 Overseers, and 10 Clerks.

The following is the scale I have allowed for quarters for these, including Office accommodation :—

	Temporary quarters.	Permanent quarters.
	Rs.	Rs.
Superintending Engineer	3,000	12,000
5 Executive Engineers	10,000	40,000
17 Assistant Engineers	17,000	68,000
78 Subordinates and Clerks...	39,000	1,56,000
	69,000	
Add 25 per cent. for changes of temporary quarters	17,250	
Total ...	86,250	2,76,000
Grand Total ...		3,62,250

For each Officer the charges will appear thus in the General Estimate.

	Temporary quarters.	Add 25 per cent. for probable changes.	Permanent quarters.	Total.
Superintending Engineer ...	3,000	...	12.000	15,000
Executive Engineers	2,000	500	8,000	10,500
Assistant Engineers	1,000	250	4,000	5,250
Subordinates and Clerks ...	500	125	2,000	2,625

The number of permanent residences might be somewhat reduced, as part of the establishment will of course be discharged on the completion of the works; but on the other hand there will be other Officers appointed for the collection of the revenue.

The Canal Chokees or Station Houses are, in accordance with the custom on the canals in Northern India, of two classes. The first class affording accommodation for a few days for an Engineer with his Assistant or Subordinate on inspection duty, and the second class accommodation for more temporary visits of the same sort; both also having rooms for stores, for native subordinates and for servants, and stables. I allow one first class Chokee at every Escape which will give a distance of 15 miles on the average, and a second class Chokee at every lock and fall, or other important work (not bridges) on the line, unless very close together. The amount required will be found entered in the estimate at the rate of Rs. 2,000 for the first and Rs. 800 for the second class Chokee.

The Soane Canals being within 300 to 350 miles of Calcutta, will not require such expensive workshops as were necessary for the Ganges and Baree Doab Canals. I have set down Rs. 50,000 for the Upper Division including the Head-works, and Rs. 10,000 for each of the other Divisions. These sums are merely for buildings for the workshops and store-rooms. The plant and tools will all be provided out of the rates for the work, except the machinery and plant, rolling stock, &c., for the Head-works, which has been separately provided for.

SECTION VIII.—PLAN OF THE HEAD WORKS.

The general plan of these is shown in Plate VIII., and other details will be found in Plates VII., IX. and X.; the two latter containing detailed plans of the works. These are on the general design which has been arrived at by the Madras Engineers in their large experience of such works; namely, a Dam with a wide rough stone apron right across the river, and sluices and locks above it, for the supply and navigation of the canals.

The large Dams established by the Madras Engineers on the Godavery and Kistna raise the water 12 and 16 feet respectively above the dry season level. The former is in four parts (the river dividing into four at the head of the delta), having a united length of nearly 4,000 yards. The Kistna dam is a single work of 1,100 yards. The greatest flood rise of the Godavery is 32 feet, and of the Kistna 38 feet. The slopes of the beds of the rivers are irregular, but average 8½ and 13 inches to the mile respectively. The foundations of these works rest entirely on sand of unknown depth, and the masonry does not reach to more than 6 or 7 feet below the summer level, the mass of the work consisting of blocks of dry stone thrown into the river bed for a width of 150 or 200 feet right across it. In heavy floods the water flows over the whole work, and scarcely a ripple indicates the position of the dams. The greatest action on the work is found to be when there is but 6 or 8 feet of water passing over the dams.

I have already mentioned that the width of the Soane where I propose to form the dam is about 3,200 yards. The flood rise of the river ordinarily does not exceed 16 feet, and I could find no account of the water ever having risen much higher. I assume however the extreme flood rise to be 20 feet. The declivity of the bed is much greater than in the cases of the Godavery and Kistna, being 3 feet per mile.

The first question that arises is as to the height to which it will be proper to raise the dam above the summer level. I propose not to attempt to raise it more than 6 feet. This will lead to some inconvenience and expense in constructing the works, because, the Western Canal being 7½ feet deep, the floorings

will have to be laid below the level of the dry season stream of the Soane. It will be seen from the sections in Plate IV., that this small elevation of the water will necessitate heavy cutting in the first 7 miles of the Western, and 10 miles of the Eastern Canals. It also gives more unfavourable levels for the passage both of the Tootla and Kao drainage on the west, as will be seen further on. It moreover deprives the canals of the command of ground for irrigation to the extent of about 10 square miles on the west, and perhaps 100 on the east* side of the river. But on the other hand we have to deal in the Soane with a river of a much greater declivity than those of the Madras works quoted, and having a less ample flood rise, so as rather to aggravate than diminish the violence of its action on the works. Under these circumstances, I have not thought it prudent to rest the whole scheme on the prospect of success in what might be deemed a work of risk—a dam to raise the water surface 12 or 14 feet. But again there is another practical consideration which has weighed with me greatly in coming to this determination. Not only should we be entirely dependent for the success of the whole scheme on the success of the dam at the head of the canals, but we should be unable to obtain a drop of water for irrigation or navigation until this great work had advanced far towards completion. To attempt to construct a high dam would therefore be a source not only of risk, but of delay in giving the districts the benefit of the water, and in obtaining for the capitalist a return for his money. I have therefore rejected the attempt.

Under my proposal of raising the water only 6 feet, all risk of failure in the work itself is avoided, and we shall be able to commence the irrigation not only before the dam is near completion, but before it is even begun.

The method by which this is managed is as follows :—Colonel Baird Smith in his Report on the Madras Works has suggested that it would be an improvement to place the locks a considerable

* To raise the canal 10 feet higher would place the Tikaree branch in its whole length perhaps 2 miles to the south of the position now sketched, and give it the command of the country between the new line and the old one.

distance above the dams, so as to save boats the risk of being carried over in those states of the river when such a thing would be dangerous, if not certain destruction. I have adopted this suggestion, and placed my lock channel head (see Plate VIII.) half a mile above the dam. The lock channel bed on the western side rising by regular gradation at the rate of 0·75 foot per mile will reach the river with a level of only 4 inches above that of the canal bed at its head. But the river surface rising at 3 feet per mile will at the lock channel head be 18 inches higher than at the canal head. At the latter place the dam is calculated to raise the water 6 feet, and the depth of the canal water is 7½ feet; so that, *without any dam,* there would be 1½ feet of water on the sill of the canal sluices; and at the lock channel head there will be (18 minus 4 or) 14 inches more. Using the lock channel head as a source of supply, therefore, we shall get nearly 3 feet of water into the western canal without constructing any dam at all. On the eastern side we should not obtain so much, because the bed of the canal is at its head only 1½ inches below the low water level of the river, and the lock channel is only ⅜ths of a mile above the dam; but even here we should obtain 15 inches on the sill of the Lock Channel Head.

But further it is certain that we shall be able to raise the level of the water some 2 or 3 feet by temporary expedients, without the use of a permanent dam; and I therefore calculate on being able to obtain nearly half the supply of water needed to fill the canals without the construction of the permanent dam. I have consequently not only placed double locks at the heads of the lock channels, but have added a set of additional sluices, so as to make the Lock Channel Heads efficient as heads of supply for the canal while the permanent dam is under construction, and have made the lock channel of the same size as the main canal.

The Lock Channel Head could not be relied upon as the permanent canal head, because we cannot, after the temporary works for raising the water shall have been thrown out of use, depend upon the dry season streams of the river keeping close to the sides so far up the river above the side sluices of the permanent dam.

I have estimated for a temporary dam of piles and clay right across the river, at a cost of Rs. 2,24,469. But it is probable that the whole of the work will not be required. It should be constructed in portions, from year to year, as the necessities of each year's demand for water may dictate.

Mr. Bingham, of Chynepoor, who has had the opportunity for many years of observing the Soane, is confident that the construction of a permanent dam might be avoided altogether, by encouraging the growth of a species of weed which flourishes in patches in the bed of the Soane, and occasionally gives rise to the formation of islands. I do not share in Mr. Bingham's anticipations of success from this plan; but there will be no difficulty in trying the experiment.

The plan of the Western Canal Lock Channel Head will be found in Plate X. It consists of two locks of 120 × 16 feet on the flanks with five intermediate arches containing each four sluices of 8 × 3 feet. A bridge passes over the work at the tail of the locks, and below this is a flooring, first of masonry for 30 feet, and then of dry-stone for 45 feet more, to protect the tail of the works from the effect of the scour. The whole extent of the work is 255 × 192 feet, omitting 100 feet of step revetment on each side of the river bank. The foundations rest on blocks under-sunk 20 feet by a process usual in India, and which will be referred to more fully below.

The cost of the work as estimated will be Rs. 1,33,943.

On the eastern side the plan of the work will be the same, except that there will be only three arches between the locks, and that, as the foundations will rest on rock, no block-sinking or step revetments are necessary. The cost of the work here will be Rs. 60,151.

It will be observed that the floor of the locks has been laid on a level, the upper and lower gates being of the same height, so that boats may be admitted when the river is low as well as when it is in flood. The flooring will have to be laid at a depth of 3 feet below the dry season surface level of the Soane. The method proposed for doing this will be stated below, in describing the proposed permanent dam.

Half of the cost of these works may be considered as due to the construction of double locks for navigation, and the other half to the use of the works as temporary heads for the irrigation supply. The cost of the temporary heads for the canals may therefore be set down as:—

Temporary Dam	Rs.	2,24,469
Western Head	"	66,971
Eastern "	"	30,075
	Total Rs.	3,21,515

which sum (even if all were required) would be amply repaid in bringing the irrigation into operation 3 or 4 years earlier than would be possible if the permanent Dam and Head-works were alone to be relied on. It must be borne in mind that the sum realized by these means will not be merely the small amount of revenue that will be derived from the use of the water in the first three years, but the increase arising from the more advanced stage of progress of the revenue during the whole 10 or 20 years the canals may take to grow to full maturity of operation.

But further, if, as is probable, it be found desirable to attempt at first only a portion of the works, it will be a great advantage to have to charge that portion with these cheap head works only, instead of the costly permanent ones, and to reserve the outlay on the latter till it might be deemed desirable to carry out the entire scheme.

I now proceed to describe the permanent Dam and Head-works, of which the designs will be found in Plates VIII. and IX.; and first the Dam.

The works are, in all essentials, of the same plan as has been successfully carried out by the Madras Engineers on the Godavery and Kistna. They consist of a masonry dam with dry stone apron across the Soane, having side openings, so as to be able to discharge something more than the dry season stream of the river, without interrupting the road-way across the crest of the dam, and to ensure the greatest scour of the subsiding river, and therefore the water of the dry season stream, being at the sides in

convenient positions to feed the canal heads. The Head Regulating Bridges of the canals are placed in close proximity to these side sluices of the Dam. The openings in them chiefly consist of small sluices in solid dam walls, so as to be easily worked under a heavy head of water; but in each head bridge there are two open arches of 18 feet width for the passage of boats, in case of the Lock Channel Head being left dry after the subsidence of the annual floods. These side openings would be permanently closed for the rainy season by massive drop gates, as soon as the river rises sufficiently to make the locks above available.

The sills of the dam sluices are to be 3 feet below the lowest summer level, taken as 347·09 above the zero of the levels—that is, they will be at 344·07.

The crest of the dam will be 6 feet above the lowest summer level—or 353·09. The top of the sluice openings will be 2 feet below this, or 351·09.

Hence there will be a height of 7 feet from the floor to the top of the sluice openings; and a head of 2 feet on the openings by the time the dam is topped by a rise of the water. This head will give a velocity of about 7 feet per second, with the ordinary co-efficient.

I propose to make the width of the sluices 6 feet, and to give 40 on the western, and 24 on the eastern bank, in all 64. These will discharge nearly 20,000 cubic feet per second before the dam is topped. This will save inconvenience from slight rises of the Soane in the dry season, and will afford ample scour to keep the low water channel near the canal heads.

The crest of the Dam being 6 inches above the intended full-supply level of the canals, there will be ample head to produce the necessary velocity in the stream, allowing only the same water-way through the sluices that is given to the canal channels, viz.:—

$$\text{Western } (73+11\tfrac{1}{4})\times 7\tfrac{1}{2}=84\tfrac{1}{4}\times 7\tfrac{1}{2}$$
$$\text{Eastern } (52+9)\times 6\tfrac{1}{2}=61\times 6\tfrac{1}{2}$$

Deducting two side openings of 18 feet each for boats, there will remain 48 feet water-way in the western, and 25 in the eastern, to provide for by means of sluices. I propose however to give 28

sluices of 3 feet wide to the former, and 20 for the latter, giving the boat openings as extra. The boat arches will be kept closed in the rains, and it may be convenient, in case of the river being low, to work the canal with the smaller openings only, under a low head.

I have deviated from the Madras model in the block-sinking for the foundations of the masonry. The Madras dams have blocks or wells sunk, sometimes only in a single row, 6 or 7 feet below the dry season stream. I have proposed a double row of blocks sunk 20 feet, the two rows breaking joint. The advantages I expect to gain by this are first, additional security for the work, and secondly, an increase of the supply of water. The first advantage I do not lay much stress on. The Madras works are perhaps sufficiently secure as they are,* and the peculiarities of the Soane with a dam of only 6 feet high do not imperatively require such additional security. Still it is an advantage.

* The following account of an accident to the Godavery works shows that deeper foundations would be advantageous, though doubtless increased breadth of flooring may be relied upon for security in preference to greater depth.

Extract from Captain Orr's Report, No. 181, *dated* 19*th June* 1850.

Para. 2. I have delayed the transmission of the above Statement for a few days, having to report the partial destruction of the Rallee under sluices, and not being able hitherto, to say how far the damage sustained might extend. The river began to fill on the 9th instant, and has risen steadily till it is now passing 10 inches deep over the highest part of the annicut. While the water was rising to the level of the annicut, the whole river passed through the Dowlaiswaram and Rallee under sluices, which discharged it with intense and increasing velocity. On Monday morning, the 17th, it having been observed that the rough stone apron behind the Rallee under sluices had sunk, the vents were closed, and immediate measures were taken to fill up the hole left behind the rear retaining wall. By 2 P. M., some progress had been made in replacing the stone, and I considered the work safe for the short time required to make up the apron to its full breadth; when suddenly, the pressure was seen to force the sand from beneath the foundation into the hollow behind the rear retaining wall, and instantly a portion of the masonry apron fell in, followed by the subsidence of one of the piers. Pier fell after pier, but the tenacity and massiveness of the masonry was such, that in falling it formed a dam, preventing any great rush of water, and thereby giving time for measures being taken to check the extension of the damage. Up to this time, seven out of the fourteen piers have fallen, leaving the two abutments and seven piers still standing, though two of the latter are much shaken. No change has taken place since last night; and as rough stone is rapidly being thrown in to protect what remains of the sluice, I trust no more of it will be

To the second reason I attach the chief importance. The bed of the Soane, 2 miles wide, and consisting, as I suppose, to a great depth of coarse sand and shingle, is an immense filter. The visible stream of the dry season is only a part of the discharge of the river, and is the part which is most affected by the vicissitudes of dry and wet seasons. It had fallen to 950 cubic feet per second in May 1861. Now if we interpose such an obstacle as a double row of blocks 20 feet deep across this filter, it will, I doubt not, force a large increased supply to the surface. The Canal Officers of Upper India are familiar with the fact that even when the Jumna Canals absorb the whole visible stream of that river, the water appears again a few miles down, and 30 miles below the dam is in most places unfordable, although it receives no affluents. Sir P. Cautley calculates the portion of the percolation which thus again rises to the surface as not much less than half the visible discharge of the river. (See his late Report on the Ganges Canal, Vol. I., pages 42—5.)

Referring to the estimate at pages lix., lx. of the Appendices, it will be seen that the total cost of the Dam is estimated by me at Rs. 11,29,269. The foundation blocks contain 1,281,426 cubic feet of masonry. If the two 20 feet lines were exchanged for one of 10 feet, we should save ¾th of this, which at Rs. 15 the 100 feet comes to Rs. 1,44,160; half the cost of the curb frames, or

lost, and that no breach at the spot will be formed. If successful, as I hope, in preventing the latter, the rebuilding of the sluice will be no difficult matter, and will only affect the completion of the work so far as the loss of the use of the sluice will delay the lowering of the level of the river at the end of the freshes.

3. The cause of this misfortune is clearly the inadequacy of the masonry apron, which instead of being 25 feet, ought to be 20 yards wide at the least, in rear of the vents, and the insufficiency of the rough stone apron, which, though made far stronger than was originally intended, and appearing substantial enough, as far as my judgment and experience could decide, has proved quite unequal to resist the force of the discharge through the sluice, even when the annicut is only 10′ 10″ instead of its ultimate height of 14 feet. The rough apron in rear of the Dowlaiswaram under sluice, although exposed to a more severe test, has hitherto shown no signs of weakness, which I attribute to its having been severely tried three successive years, and at the end of each greatly strengthened by the addition of more stone, till it has acquired sufficient thickness and stability. The Rallee sluice apron unfortunately has not thus been gradually tested. As a matter of precaution, however, I have partially closed the vents of the Dowlaiswaram sluices, and will take the first opportunity to examine and, if necessary, to further strengthen its apron.—*From the Madras Engineer Papers, Vol. III., page* 151.

Rs. 18,475; and, as explained in the note below,* seven-tenths of the cost of sinking on each block retained, or Rs. 1,25,630 in all, which, with a share of the sum allowed for contingencies, come to Rs. 3,02,678; leaving the cost of the dam reduced to Rs. 8,26,591, exclusive of the cost of plant (Rs. 2,50,000.) Including the plant, the reduction would be from Rs. 13,79,269 to Rs. 10,76,591. This is the largest reduction that could be made on this account in my estimate; but I would recommend that the estimate be allowed to stand in full.

* The English Engineer will finl the process described in papers by Sir P. Cautley in the "Corps Papers" of the Royal Engineers by Vol. I. page 50, and Lieut. (now Lieut. Col.) Yule, in the 1st Volume New Series of the Professional Papers of the Royal Engineers, 1851.

Lieut. Col. A. G. Goodwyn has deduced from his experience on the Ganges Canal works the approximate rule that the cost of sinking may be taken at Rs. 1½ per 100 cubic feet of the *crater* that it would be necessary to form to build the block dry in the position in which it is finally intended to stand—that is, the cubic content of the frustrum of a pyramid or cone of which the point is downwards, and the small end equal to the area of the horizontal section of the block, the sides being at the angle of 45° with the horizon. But if the blocks be sunk contiguous to each other, the crater must be taken for the whole set, and each will bear its share of the total. This is because the blocks mutually precipitate each other's descent in such cases. Calculating in this way the sinking of the blocks 13 × 7 in one line across the Soane would cost Rs. 91 each if 20 feet deep, Rs. 55½ if 15 feet deep, and Rs. 37½ if 12 feet deep, Rs. 28½ if 10 feet deep, &c.

The 20 feet blocks in the head works, being uniformly of the full size of 13 × 7 I have taken the cost in sinking Rs. 100 each.

15 feet blocks in the other works, when there is a considerable mixture of smaller sizes, I have taken at Rs. 50 each block all round.

12 feet blocks in like manner, I have taken at Rs. 30 each.

The narrow rectangular block which I have almost uniformly adopted in the designs is one that was strongly recommended to me as much more easily worked than either wells, or blocks with several hollows. The experience of Engineers, however, differs on this point. On the Ganges Canal long narrow blocks were found more difficult to manage than others. On the Railway bridge works at the Soane great advantage was derived from substituting large wells of 18 feet interior diameter for the clusters of small wells which at first were tried. The suitability of the long narrow blocks for the dam across the Soane is obvious. Experiment alone can decide what kind of block will be the best on the whole. But it must not be forgotten that we may be able to dispense with block-sinking altogether, except for the dam and head works; and for these it may be found better to introduce the pneumatic process which has lately been tried with success on the Eastern Bengal Railway works.

The dam, it will be perceived, is to consist of a plain wall of good rubble masonry supported on this double row of blocks which has just been discussed, with a dry stone apron of 135 feet wide all along the down-stream side of the masonry. This dry stone apron in fact is the largest item of expense in the dam. No work of the kind has yet been done in this Presidency; but I find in the Madras works that the rate for such work has been as nearly as possible 10 annas per cubic yard, or in round numbers Rs. 2½ per 100 cubic feet. This rate does not include, as I understand, any portion of the cost of the plant and rolling stock for the railways used to convey the stone from the quarries to the site of the works. This plant (or rather the whole plant, of which this was I believe the greater part) as set down in the last account of the Kistna works (Madras Engineer Papers, Vol. IV., page 70.) is Rs. 1,41,142 on a total outlay of Rs. 7,49,367* including the Head-

* I give the table in full, all but the columns referring to the individual month's work, and the annas and pies.

Description of Work.	Estimated.		Total amount and value of work performed up to the end of April 1855.	
	Cubic yards.	Amount. Rs.	Cubic yards.	Amount. Rs.
Rough stone	2,28,602	1,57,164	3,72,744	2,56,262
Rubble	53,916	1,28,050	51,663	1,22,711
Cut-stone	16,223	82,225	5,499	27,495
Partially dressed stone	1,092	3,276	3,479	10,439
Brick in chunam	2,001	5,429	1,593	4,777
Earth-work, excavating foundations, &c.	7,75,000	48,437	9,18,611	63,072
Wells ... ... No.	2,299	16,457	1,784	12,488
Contingencies, sundries, plastering, &c.	...	1,03,800		
Plant	...	1,11,407	...	1,41,142
Pay of Officers, superintendence, &c.	...	85,936	...	68,773
Grouting	...	5,000		
Opening quarry	...	7,000	...	7,303
Sluice shutters ... ... No.	62	1,860	...	2,940
Lock gates, ...pairs	6	9,500	...	10,247
Embanking river	...	1,000	...	80
Total	...	7,66,541	...	7,27,730

works as well as dam, the latter being, as before stated, 1,100 yards long. Having no experience as to the cost of work of this kind on a large scale in this Presidency, I have not thought it safe to estimate so low as the rate which was obtained for the Madras works, although there is no material difference in the price of labour, as far as I can ascertain, and though the carriage will be for a less distance than in the case of the Godavery works, but greater than in the case of the Kistna. I have taken the rate at Rs. 4 per 100 cubic feet and have allowed besides Rs. 2,50,000 for plant, as a separate charge. The dry stone-work done on the Ganges and Baree Doab Canals is generally rated at Rs. 6 to 6½ the 100 cubic feet, but this is without the assistance of carriage by rail. The rate I have assumed, if the plant be included in the cost, will amount to about Rs. 6, so that I feel confident that the rate is a safe one, and hope that some saving will be effected in the execution of the work. The plant will chiefly consist of rails and waggons. The experience gained on the Ganges Canal works points out that all the iron-work should be obtained direct from England, and that the waggons should tilt to the side and not in front.

The stone will be obtained from the river bank or any part of the low range of hills shown in Plate VII. on the right or east bank of the river, and from the foot of the Kymore range, 2 miles distant from the river bank, on the left or west side. Considering the width of the river, the average distance of carriage will probably amount to three times the distance in the case of the Kistna works where the stone quarries were close to the works; and the distance of the proposed site of the Soane Canal works from the sea will enhance the cost of the carriage of the iron-work to the site. I think therefore the cost of the plant cannot safely be estimated at less than 2½ lakhs of Rupees, being an increase of 66 per cent. on that for the Kistna works. In this I include the cost of laying down the rails with all the works necessary to that end. I have not thought it necessary in the present stage of the project to go into further detail as to the Railways and other plant.

I have already stated that the flooring of the side sluices of the Dam will have to be laid 3 feet below the ordinary surface level of the dry season stream of the Soane. I now describe the method proposed for doing this.

The stream must first, if necessary, be turned, and the channel filled up with sand to the water level. The masonry blocks will then be sunk all round the space on which the floor is to be laid, the last 5 feet of the block being built upon a thin wooden frame, so as to admit of being broken up afterwards without disturbing the masonry below. Then the sand is to be excavated as far as possible from the outer side of the blocks for 15 or 20 feet, and clay rammed down to the depth of at least 6 or 8 feet. The blocks will also be filled in with clay to within 5 feet of the top. The sand will then be excavated from the whole interior space to a depth of 8 feet below the water. This may be facilitated by raking it together by means of large hoes drawn by ropes. Having excavated the sand, concrete will be thrown in (using boats) unslaked, either in thin bags or loose, and will then be well rammed, so as to secure a 3 feet layer all over the area to be floored. As soon as the concrete has set, the water will be pumped out, the upper 5 feet of the blocks will be removed, and the flooring (2 feet thick) laid dry in a water-tight (or nearly water-tight) cistern 5 feet deep, of which the clay will form the sides and the concrete the bottom. I have allowed Rs. 50,000 in the estimate, in addition to the cost of the blocks and concrete (charged at the same rate as masonry), to cover the cost of this work, and such other diversions of the stream and removals of sand as may be necessary during the progress of the works.

In the Madras dams the flooring of the side sluices, owing to the great degree in which the level of the water was raised, was not below the level of the summer stream. The following extract from Captain Orr's Report* of 30th July 1852, shows the method used by him to fill up, and carry the dam across, the channel of the dry season stream, which in the Kistna was much deeper than anything we have to deal with on the Soane :—

"3.—The foundations of the under sluices, at each end of the annicut, will be laid as soon as the river shall have fallen sufficiently; and their construction will be pushed on as rapidly as practicable, in order that, if possible, the floors may be laid during the season, so as to allow the vents to be made use of the following year as outlets for the river, while the body of the dam is in progress.

* Madras Engineer Papers, Volume IV., page 38.

"4.—It has been found at the Godavery, that, when the body of the annicut rested on a mass of loose stone thrown in to fill up hollows in the river bed, as at the sites of the various breaches that occurred during the progress of the work, it was not only difficult, but almost impossible, to render the dam water-tight; the leakage at those places being not mere percolation, as along the rest of the work which was supported on wells sunk in the sand, but strong continuous streams, flowing at a great depth through the large open interstices of the rough stones, as through inverted syphons. As there can be no doubt that the same thing would occur here, wherever the annicut should rest upon rough stone thrown in to fill up the hollows in the bed of this river, it is my intention not to fill in these hollows on the line of the body of the work, but on that of the apron, and then to fill up in front to the proper level with sand, on which wells will be sunk and thereon the annicut be built."

In the plan of the side sluices of the dam I have deviated from the Madras model in keeping the road-way over those openings on the same level as the rest of the dam, instead of raising it by a gradual slope to the level of the top of the river bank. In the Madras plan the road-way over these side sluices forms the ramp by which to ascend from the level of the dam top to the embankment at the river side. In my plan the ramp has to be formed as a separate work by excavation within the embankment. My object in this change was simply to avoid the additional obstruction to the stream which the raised mass of masonry at the flanks causes. I do not think that there is any objection to this change on the score of courting too much action on the side of the river near the works, considering the ample protection given to the bank.

Nor do I think there will be any difficulty in working the simple apparatus of vertical stop boards to the openings in the side bridges. They may be secured by ropes to the shore, and so removed without difficulty in case of any very sudden rise of the river. It is however very unlikely that any such rise would take place as to render it difficult to remove the stop boards by degrees by hand.

The cost of the Head Regulating bridges, as will be seen in Estimate No. 3 in the Appendix, is for the

Western Canal	...	...	Rs. 1,46,346
Eastern Canal	...	...	" 33,712

The great difference arises, first from the larger size of the Western Canal; second from the Eastern Canal Head-bridge being founded on rock, and third from the cost of protective works along one mile of the river bank being included in the Estimate for the Western Canal Head-bridge, to the amount of Rs. 40,052.

SECTION IX.—ALIGNMENT OF THE CANALS.

A.—Western Canal, Main Line.

Passing from the head works the canal will soon come to the deep cutting west and north of the village of Tooma or Toomba. This deep cutting is, as has already been mentioned, occasioned by the small degree in which I have thought it proper to raise the river water by the Dam. The most suitable line for the canal to take, as regards level, would be through the village of Tooma; west of it deep cutting is necessary, and east of it there is only low land liable to flood. A similar case will be noticed on the right bank of the Soane, where there is low *khadir* land, and where, as here, the villages are placed on the very lowest safe portion of the high bank above it, so as to be as near as possible to their cultivation, and yet out of the reach of the floods. I have not thought it worth while to disturb the village, though doubtless the cost of constructing a new one and taking the canal through the land now occupied by the village would be cheaper than the present heavy cutting.

After passing Tooma the canal line is kept as low as possible (see Section F, Plate IV.), but still in heavy cutting, to nearly the end of the 7th mile, where it comes upon the Tootla drainage, which is sketched in some detail on Plate IV. Three 10 feet inlets* are required at the sites shown in Plate VIII., and two others for small water-courses at the end of the 2nd and in the 5th mile. Two larger nalas at the end of the 3rd, and in the 6th mile are

* Plate XIII. contains the designs for Inlets and Escapes. They are on the ordinary plans, and do not require any special remarks.

provided for by 20 feet inlets; but, if possible, they should be passed over the canal by bridges which will not the less answer for ordinary village communication, so that the arrangement will tend at once to efficiency and economy.

The small River Tootla drains about six square miles of country on the table-land of the Kymore range, from which it descends by a fine water-fall (in the rains) and runs for about three miles in the plains till it comes to a flat tract, in which it is lost. The channel when it emerges from the recess in which is the water-fall, is above 100 feet wide, with a boulder bottom. Where the canal line of 1857 crosses it (Plate IV.), it has a bold well defined channel, of the Section shown in Plate IV. But after that it begins to diminish in width and depth till it becomes a ditch 2 feet wide, and then finally disappears in the flat tract marked on the map, which becomes a swamp or *jheel* in the rains. Into this also run, and in like manner are lost, the other water-courses from the hill side further north. (All these channels are dry, except during the rainy season.)

A reference to Sections G and H will show the cause of this phenomenon—it is simply that there is no fall of the ground towards the Soane, and only a very slight fall to the north. When the floods are severe they chiefly find vent by the channels which again issue from the jheel towards Tilothoo. But in ordinary cases most of the water in this natural reservoir is used for the rice crops, and issues finally by the passages south of Maharajgunj, south of Putlooka, and west of Hoorka. Near Maharajgunj there is a dam to turn the waters north-east.

The whole of the drainage collected in this bason is that of about 6 square miles in the hills and 16 in the plains, or 22 square miles in all. Sir P. Cautley estimates the maximum flood discharge in such cases at half an inch per hour from the whole area, which gives 323 cubic feet per second from each square mile. The whole discharge in this case may therefore be reckoned at full flood as equal to 7,106 cubic feet per second. But again we have the level of the bed of the Tootla where it issues upon the plains 379·17 feet above datum, and where it is crossed by Section G. in Plate IV. it is 359·49. The difference is 19·68 feet in about two miles.

The area of the section at the point where the canal line of 1857 crosses is 322 square feet, and the flood height here is well known, being close to the Indigo Factory bridge. The ordinary rules give a velocity here of 9·22 feet per second, and hence we have a flood discharge of 2,968 cubic feet per second for the Tootla alone, which carries rather less than half the whole drainage. Hence the estimate of 7,106 feet per second for the whole drainage, as calculated in Sir P. Cautley's method, is confirmed by this independent determination.

It will be seen that the canal line enters the jheel at the end of the 7th mile, and from this to the end of the 8th the levels are awkward, the canal being in 12 feet cutting, and having its surface therefore 4½ feet below the soil above which is the jheel water. The drainage water might be carried over the canal with ease, but for the necessity of preserving a good head-way for navigation. To carry it through the canal at such levels would be very awkward; and the only alternative of passing it under the canal requires deep and costly syphon drains.* I have designed five of these, with 10 openings of 6 × 5 feet in each. Each drain of 10 openings, under a head of 1 foot of water on the up-stream side, will pass 1,500 cubic feet a second, and will cost Rs. 57,313 if under-sunk foundations are necessary, or Rs. 42,838 with ordinary foundations. For five drains the cost would be Rs. 2,86,565 or 2,14,190, according to the nature of the foundations. I propose to place them as nearly as possible where the drainage now crosses the country—three in the 8th mile, one near the end of the 9th, and the fifth near the end of the 10th mile of the canal line.

By cutting channels for the drainage, however, from the canal line towards the Soane, we shall be able to reduce the level of the drainage water, and so pass it by dam, or by less costly syphons. I have preferred the latter expedient at a cost of Rs. 3,10,980, to the former at a cost of Rs. 2,30,290. The advantage of keeping the drainage water out of the canal more than makes up for the difference of cost. The Estimates in both cases include the cost of under-sunk foundations, and if we are able to dispense with these,

* Plate XI., and Appendix, page lxxvi.

the amounts will be reduced to Rs. 2,31,695 and Rs. 1,56,785 respectively. The details of the works will be found in Plate XI., and in the Estimate No. 5, Appendix, pages lxxvi. to lxxx.

The necessity for such expensive works for crossing this comparatively small drainage, suggests the possible advantage of adopting some other line where less costly works will answer. I do not think, however, that any better line can be had. To go further towards the hills would certainly enable us to cross the drainage at a better level, but it would necessitate heavier cutting or very great and undesirable winding of the channel. The only line further east that is at all likely to succeed better is one carried nearly along the line of the road parallel and near to the Soane bank, which I first proposed for the Western Soane Canal. On this the Tootla and Bustipoor nala would be crossed near the Soane, where they are well developed and have large defined channels. To reap the whole advantage of this line in crossing the drainage where fully developed, it would be necessary to carry the main line to Bustipoor near Dehree, which would make the detour for the Sasseram Branch very great. On the whole, I do not anticipate any advantage, but it would be satisfactory to have this alternative line fully investigated before the line I have proposed is finally adopted.

The main line terminates after $10\frac{1}{3}$ miles, and divides, at the end of the Tootla drainage valley, into the Arrah and Sasseram Branches.

B.—Arrah Branch with its subordinate lines.

The Arrah Branch is to carry 877 cubic feet per second, with a width at bottom of $42\frac{1}{2}$ feet, $5\frac{1}{2}$ feet depth of water, and 1·04 feet of fall per mile. It divides into branches as follows:—At 32 miles from the main canal head it gives off the Ranipoor Branch, at $40\frac{1}{2}$ miles the Peeroo Branch, and at the 56th mile the Nansaugor Branch. The Peeroo Branch also gives off the Jugdispoor Branch. The dimensions of all these will be found given in the Table in Section 5.

At the 13th mile from the Head of the Main Canal, the Arrah Branch crosses a small ill defined nala near Nowadeeh.

This nala drains an area of 4 square miles, and its greatest discharge may be reckoned at 1,300 cubic feet per second. It might therefore well be passed under the canal in the same way as the Tootla drainage, but at less cost, the levels being more favourable. I have however laid out the Section to cross it on a level by inlet and dam. This I think should be altered in executing the work, and I have provided in the estimate Rs. 50,000 for the passage of this drainage by syphon or aqueduct, the fall being removed from the 13th mile to the 14th, that is, below the passage of the nala.

This is I believe the last drainage that will have to be passed across the canal on this line. For the rest of its course it should keep on the water-shed of the country. It is evident that an error has been made in laying out the latter part of the Arrah Branch, which should proceed from the 54th mile west of Buroonan on Section S, to near Shapoor on Section T and to near Kusap on Section V, falling into the Bunas near Usnee. The detailed examination of the country does not however extend beyond the Grand Trunk Road,* and I can only say with Sir P. Cautley :—

"The want of detailed surveys of the superficial lines of drainage and hollows which intersect the surface of the country over which the line of canal runs will prevent my entering into a description of the subordinate cuts which will be required for relieving the canal and the country from intercepted drainage. The rule, however, which I have before adverted to, as that which have been our guide in the main canal works, is, I believe, to be recommended, viz., to draw away from the canal alignment all intercepted water, and to carry it by artificial cuts into the natural lines of drainage lying on the right and left."—Volume I., page 395, Sir P. Cautley's Report.

* The best method of completing the detailed survey of the country will be this:—First to obtain from the Surveyor General's Office tracings of the Village Maps of the Revenue Survey, which may be carefully combined so as to produce sufficiently accurate maps of large tracts of the country on a scale of 4 inches to the mile. The topographical details of these will be found very imperfect, as the Revenue Survey, at the time Shahabad and Behar were surveyed, undertook no details that were not required for Revenue purposes; but these maps will give a good basis on which to work. The plots of the levels, and detailed compass surveys of parts of the country requiring close attention should be inserted in these maps, and the topographical details otherwise improved.

But though there should be no direct drainage to pass across the lower parts of the Arrah Branch, there are flood waters from the Soane to be dealt with as follows:—

The Soane floods first appear on the west bank at Umeāwur south of Nasreegunj (Plate V.,) in the 31st mile of the canal line, but they do not cross the country, and may easily be embanked off or avoided by a slight change of line, so I understand from Captain Farrington's note on the subject.

The next point where the floods are met with is just above Nonore, where they cross both the Arrah and Nansaugor branches but in very slight volume. An inlet of 100, and escape of 150 feet will be provided in the estimate on the Arrah Branch, but it will possibly not be required in actual construction.

Below Turkoul the Soane floods pass nearly due north to the angle of the Nugree in considerable volume, passing the Nansaugor branch in the 13th and 14th miles. Again from about Bishoonpoor to Furhungpoor there are, here and there, heavily flooded tracts, passing the branch from the 16th to the 21st mile. The depth of flood does not appear any where to exceed 3 feet in ordinary cases. As the Nansaugor branch is little more than a ditch, I do not propose to make any provision for the passage of these floods beyond leaving ample openings in the spoil banks and supplying regulating planks to one or two bridges to prevent the floods passing down the line. In ordinary cases they will probably do very little injury, and whatever damage they do may be repaired annually at no great cost.

In connexion with this subject it may be noticed here that there are a few native irrigation channels from the Soane on this bank, which are used only for conducting its flood waters in the rains. They are what in the Punjab would be called small Inundation Canals. In Behar they are called *Pyens.* One passes the Arrah branch at the end of the 42nd mile into the *jheel* at Dunwar. Another flows into the country a short distance above Behta (at the 43¼ mile); it probably joins the head of the Banas to the Soane; and a third extends from Undharee to Junpooreea, crossing the canal at the 49th mile. Inlets and escapes are provided for all these, but they will perhaps not be required, as the canal irrigation will supersede the use of these Pyens.

The termini of the Arrah and Nansaugor Branches have been carried in the lines of levels by Captain Farrington beyond the Railway. This was not intended by me, and should be altered when the lines are finally laid out.

C.—Sasseram Branch and its subordinate lines.

The Sasseram Branch where it leaves the main canal is to have a discharge of 1,091 cubic feet per second, a width at bottom of 49 feet, depth of water 6 feet, and fall per mile 1 foot. From the bifurcation of the main canal the line only runs 7 miles to Kuroundea, where it divides into three branches for irrigation, and one for navigation.

These are the following :—

Sasseram Branch (lower part),
Jugjeewun Branch,
Buxar Branch,
and Sasseram Navigable line.

From these again are given off the—

Chowsa Branch,
Buradhee Branch,
Doomraon Branch,
Kochus Branch,
the Navigable line to the Kurrumnassa,
and the Main Navigable line to Benares.

The discharge and dimensions proposed for all these will be found detailed in the Table, Section V., and their directions are sketched in Plate III., except the Kurrumnassa Navigable line, which, however, is parallel to the last portion of the Chowsa Branch.

No part of the lines for these branches has been examined in detail, except that of the upper 7 miles of the Sasseram Branch, where it is intended to retain the full discharge of 1,091 cubic feet per second; and of this the line can hardly be considered as settled.

It will be observed that the line adopted is nearly straight from the bifurcation of the main canal to the Kuroundeea trifurcation. (See Plates IV. and XIX.) The line passes inside the Gonyla Hill, and will be in rather deep cutting for the whole distance

to the point where it crosses the Kao. There are four small drainage channels crossed, two near the end of the 12th, and two near the end of the 13th miles. These four do not drain in the aggregate much more than one square mile, and may be admitted into the canal by inlets with drops. Two 10 feet inlets may with a little cutting be made to answer. The cost may be set down at Rs. 9,000. The next drainage crossed is the Dhodand Nala, which intersects the line near the end of the 14th mile and carries a drainage of under 3 square miles. This will, I think, be best disposed of by a cut of 1½ miles to carry it, together with the next nala crossing the line at the 15th mile, into the Kao. The cutting required will will be on the average about 8 feet by 30, or for the mile and a half say 2 millions of cubic feet, at Rs. 2 per 1,000 = Rs. 4,000. But I suppose it will be necessary to give two bridges, each of one arch of 28 feet, which will cost Rs. 14,000 more, making Rs. 18,000 in all. The drainage will be cheaply disposed of at this sum. Adding the Rs. 9,000 above mentioned for inlets, the total charge for minor drainage works on the line will be Rs. 27,000.

The River Kao has been described in para. 32 of the Report of 1855. The branch which forms the Kao may be reckoned to have in all a drainage area of 25 square miles, and an extreme flood discharge of 8,100 cubic feet per second.

The Kao is crossed near the end of the 16th mile, where it has a width of 58 feet and a depth in flood of 14 feet, between hard well defined banks. The site would be an excellent one for an aqueduct, but the levels unfortunately forbid this. The bed of the river is 5¼ feet below the bed of the canal at the crossing, and the flood level 1½ feet above the surface level of the canal at full supply. By altering the position of the fall and locks so as to place them above the crossing, the levels might be so altered as to bring the bed of the canal 3 feet below that of the Kao, and the surface level of the canal 9 feet below that of the river. In this position the river might with no great difficulty be forced over the canal, were it not for the necessity for providing head-way for navigation. I have therefore of necessity designed a dam for this crossing. It consists of six openings of 10 feet each, giving 840 square feet of water-way; an upper bridge is added on the line of

the western bank of the canal (the dam bridge being on the east), and curtain walls across the canal bed; and the space between them and the bridge is floored over. The estimated cost is Rs. 50,321.

But the water-way of 840 square feet, though more than the natural channel of the river possesses, is little enough to pass a flood of 8,000 cubic feet per second. I have therefore proposed further to place an inlet of 50 feet water-way upon the nala which issues from the Kao above, and rejoins it with some additional drainage below the canal crossing, and to give an escape on this nala of nine openings of 10 feet each, being 720 more square feet of water-way. This escape will also serve for the regulation of the canal waters above the trifurcation.

The cost of these works would be—

	Rs.
Inlet	5,000
Escape	15,500
Total ...	20,500

A Fall and Locks for an 8 feet descent are required immediately after the passage of the Kao, and are sketched in on Plate XIX.

The Barrier Bridge and Lock Channel Heads above the fall may serve as regulators to stop the flow of the flood waters down the canal. Three more inlets of 10 feet opening each will be necessary before we come to the trifurcation, one of which will be taken in at the lock head in lieu of a Distributary issuing there, as the levels will not admit of irrigation on the west side. It will also be necessary to take the drainage into the Sasseram Branch below the trifurcation by 10 feet inlets in two cases, but after passing Adampoor (Plate XIX.) it will appear from the Section to Plate III. that the drainage may be carried by cuts into the Koodra, and from this point the canal lines dependent on the Sasseram Branch should be free from all entrance of drainage water.

In consequence of the escape being placed upon the Kao above the Grand Trunk Road crossing, it will be necessary to cons-

truct a road bridge over the Kao for the Grand Trunk Road. The existing one is only of two arches of 12½ feet span each; and though the waters of the Kao are a good deal dispersed between the points of crossing by my canal line and the Grand Trunk Road, the water-way is even now insufficient, and the bridge cannot be relied on for any extra duty. I propose therefore to give a bridge similar to my design No. IV., of two arches of 28 feet span, at a cost of Rs. 10,000. The Trunk Road will also have to be diverted, as shown in Plate XIX. The length of new road to be made will be about 5,000 feet, which with an embankment on the average 5 feet high, and 40 feet wide at crest, and 5,000 running feet of metalling 20 feet wide and 9 inches thick, will cost about Rs. 7,000.

Although the plan proposed for passing the Kao would, I believe, answer, and is cheap, it is inconvenient and not altogether satisfactory. I think it proper therefore to point out two alternatives. One is to change the line of canal and pass to the east of the Gonyla Hill, crossing the Kao below the Grand Trunk Road crossing. The only advantage of this line would be the avoidance of a dam with so great a depth of water for the passage of the Kao. We should in fact then take the floods in detail instead of meeting them all in one body. This would perhaps make the works simple, and cheaper, but it would multiply the points at which we should have the annoyance of meeting the flood waters. I do not therefore think it promises well; but it would be proper to have the country examined before the works are finally set out.

The other plan is a more tempting one to the Engineer; and, if circumstances should prove so favourable as not to make it too expensive, would be in every way very satisfactory. It is to adopt the line dotted in on Plate XIX. and terminating near the Village of Bussuntpoor; to seek a crossing higher up the Kao, where the banks may prove more bold and the soil (as I believe it will be found) firm clay, and then to force the Kao, by a super-passage and subsequent drop, over the canal. Then to make for the Gae Ghat Pass, and take the canal through it by a tunnel, using the excavated material (the rock is good hard sandstone) for the works, and taking advantage of the rock to place there a second fall. The dotted curves indicate the lines for the lock channels in this case, the

locks being supposed to be on the flanks of the fall in the tunnel or cutting, as in the case of the passage of the Raneepoor and Puttree torrents over the Ganges Canal. The tunnel or cutting through the Gae Ghat Pass is not however an essential portion of the works in this plan. If that work be found too expensive, the canal line may, after taking the higher crossing of the Kao, be carried round to the present position west of Kuroundeea.

For the super-passage of the Kao my object in proposing to go higher up the stream is partly to obtain stronger banks, a deeper channel, and more stable soil, but partly also to obtain a higher level for the bed of the river. I have already stated that at the existing crossing the canal bed may be brought 3 feet below that of the Kao. Now we require for a super-passage 6 feet for the depth of water in the canal, 13 feet for head-way for boats, and 3 feet for the thickness of the arching over the canal and below the new bed of the river; in all 22 feet. At the existing crossing therefore we should require to place an obstacle of 22—3 or 19 feet in the way of the river over which it would rise and again descend in a cataract. The Kao in its heaviest floods does not carry a volume of water greatly in excess of the Ganges Canal full discharge,* and therefore this cataract of the Kao, which would only flow occasionally, would be no greater work than the falls of the Ganges Canal, which flow continually. Now some of these falls have a 9 feet drop, so that if the fall on the Kao, as above stated, were divided into two drops, they would scarcely exceed those of the Ganges Canal upper falls. Every reduction that could be made would however very much facilitate the work, and hence the advantage of seeking for a passage higher up.

Supposing this to be obtained, the cost of the arch-way for carrying the river (with 200 feet water-way) over the canal, (allowing tow-paths) would not exceed that of 10 bridges of Design No. II., while the cost of the protection for the tail of the work from the action of the falls could hardly exceed that of two of the large 200 feet falls on the Ganges Canal, of which the cost

* Kao 8,100 cubic feet per second: Ganges Canal 6,750 cubic feet per second.

is about Rs. 80,000 each. We have then a very rough extreme estimate thus:—

		Rs.
10	Bridges as per Design No. II., at Rs. 16,000 each ...	1,60,000
2	Falls as on Ganges Canal	1,60,000
	Total ...	3,20,000

This, though a large sum, does not much exceed that estimated for the Tootla drainage, and I have included it in the general estimate. If on a detailed examination the work should be deemed unadvisable, we can fall back upon the cheaper design for a dam.

Of the remaining flowing canal lines depending on the Sasseram Branch, I have no more to say beyond what will be stated in the estimate.

It will be best to take the navigable line from Sasseram, close past the town and west of the Koodra, if it can be done without undue expense. It will then join the Main Navigation Canal to Benares after the latter has crossed the Koodra. This main line will also have to cross the Doorgowtee, Koora, Soora, and Kurumnassa. In the absence of all details I have taken the cost of the passage of these rivers at Rs. 800 per running foot of water-way, which I believe will be found a sufficient estimate, including the cost of embanked approaches.

D.—Eastern Soane Canal, Main Line.

In the first 3 miles of this line the route of 1857 corresponds very closely with that finally chosen in 1861. From the end of the 3rd mile Lieut. Whish struck into the high ground, and avoiding all drainage, carried his line through rather deep cutting for 6 miles, when it issued on the level of the plains. This course was undoubtedly judicious under the more favourable levels obtained by the canal head being at Khabra. But having now determined to place the canal head at Jhikutteea, I thought it proper to endeavour to avoid the very deep cutting which this early entry upon the high ground with the new level of head water would entail; and I therefore took the line of 1861 nearer the river, passing a great deal of small drainage and rugged country till I attained moderate cutting on the level plains at the end of the 10th mile from the head. The

cutting from 3 to 9½ miles from the head would, were Lieut. Whish's line adopted with the new head, have averaged 30 feet deep, and would have amounted for that 6½ miles to 93,000,000 cubic feet. The quantity of excavation on the line of 1861 is about 54,000,000. There is therefore a saving of 39 millions of cubic feet of excavation, which at the rate of Rs. 4 per 1,000, assumed in the estimate, comes to Rs. 1,56,000. But against this we have to put the cost of passing the drainage of a strip of country about ¾ths of a mile wide, from the 4th to the 9th mile, from which the maximum discharge of water (if we take it at 4 square miles) will be about 1,300 cubic feet per second. To pass this in the most expensive way, namely, by syphons, as in the case of the Tootla floods, will come to less than Rs. 60,000; so that the change of line gives a saving of nearly a lakh of rupees.

To return now to the details of the course of the canal. I have already mentioned that the first 4,000 feet of the main line may possibly be in rock-cutting; some portion of it certainly will be so. The same is the case with lock channel, with exception of the first 300 feet, which is in an alluvial deposit, with rock probably not higher than 3 or 4 feet below the level of the Soane low water. In this rocky piece of country there will be two inlets for nalas, as shown in Plate VII. These will descend into the canal with a drop of several feet, but their beds being of rock it will be unnecessary to provide any masonry except the bridges to carry the canal bank road. For these the cost entered in the general estimate is that for 10 feet inlets on a level (Estimate No. 9 of Appendix), Rs. 2,000 each.

The first drainage we come to after these is the Dhoondhooa Nala, which carries the drainage of the greater part of the northern face of the Putthurghatta Hill, or of about 3 square miles at the most. The discharge on the ordinary calculation would therefore be about 1,000 cubic feet per second at the heaviest.

About the middle of the 2nd and about the middle of the 3rd mile are two nalas which may drain as much as a square mile each, which the canal passes in low patches of rice fields. These cannot be turned by cuts without heavy excavation, and will therefore have to be passed across the canal. A small nala, a little

beyond the end of the 2nd mile, may be turned into the last of these. Water-way for 350 cubic feet per second should be provided for each of these passages, and an excavated channel for half a mile.

In the 4th mile we come to another nala which will require to be passed across the canal with the same water-way; and a drainage of five nalas, which may be united by cuts aggregating half a mile long, and of the section on the average of 30 × 10. The united drainage from these will discharge about 500 cubic feet per second.

The whole of the drainage which would cross the canal in the 5th and 6th miles may be united by a cut 11,000 feet long, and of a section 40 × 7, and may be passed across the canal at about 6¼ miles from the head, between Tetrahand and Mahooanwun. The discharge to be provided for will be about 500 cubic feet per second.

The drainage which crosses in the latter part of the 7th and in the 8th mile between Mahooanwun and Urkurra may be passed by a cut beyond the latter place. The cut would be about 5,000 feet long, and, to avoid heavy digging, it will be necessary to use part of the spoil earth of the canal to fill up the nalas. With this provision a depth of 10 feet on the average, and width of 40 feet, will cover the work. The drainage will be from about 1½ square miles, and will require water-way for about 400 cubic feet per second.

A drainage of about the same extent must be provided for in the 9th and commencement of the 10th mile, and will probably require two passages across the canal for 200 cubic feet per second each, with cutting of about the same extent as in the 7th and 8th miles.

The last three passages may perhaps be conveniently united into one; but for the present I leave them separate.

Resuming now, the drainage to be passed across the canal (excluding the first two inlets) is:—

Dhoondhooa Nala ...	... 1,000	cubic feet	per second.
2nd Mile ...	... 350	"	"
3rd " ...	... 350	"	"
4th " ...	... 350	"	"
" " ...	... 500	"	"
Carried over ...	2,550		

Brought forward	...	2,550	cubic feet	per second.
7th Mile	... ...	500	"	"
9th "	... ...	400	"	"
10th "	... ...	200	"	"
" "	... ...	200	"	"
Total drainage		3,850		

This will all be most conveniently passed under the canals by syphons on a somewhat similar plan to those devised for the Tootla drainage, as modified in the third proposal. Each opening of 6 × 5 may be made to pass 200 cubic feet per second as a maximum discharge, and the cost of each span may be set down at Rs. 8,000 for single spans, Rs. 6,000 each for double spans, and Rs. 5,000 for larger drains; it being borne in mind that the full supply section of aqueduct here is 61 × 6·12 feet, against 84 × 7·5, as on the Tootla.

Reckoning thus, the cost of the masonry works for the drainage will be—

		Rs.
Dhoondhooa Nala, 5 spans at Rs. 5,000	...	25,000
Drain in 2nd mile, 2 spans at Rs. 6,000	...	12,000
Ditto in 3rd ditto ditto	...	12,000
Ditto in 4th ditto ditto	...	12,000
Ditto in 4th ditto, 3 spans at Rs. 5,000	...	15,000
Ditto in 7th ditto ditto	...	15,000
Ditto in 9th ditto, 2 spans at Rs. 6,000	...	12,000
Ditto in 10th ditto, 1 span at Rs. 8,000	...	8,000
Ditto ditto	...	8,000
	Total Rs.	1,19,000

The cuts are as follows :—

3rd Mile,	2,640 ×	20 ×	6 =	316,800	
4th ditto	2,640 ×	30 ×	10 =	792,000	
5th ditto	11,000 ×	40 ×	7 =	3,080,000	
7th ditto	5,000 ×	40 ×	10 =	2,000,000	
8th ditto	5,000 ×	40 ×	10 =	2,000,000	
		Total	...	8,188,800	cubic feet.

At Rs. 3 per 1,000	Rs. 24,566
5 per cent. contingencies	" 1,229
Total Earth-work ...	Rs. 25,795
One bridge of 28 feet span over the cutting in the 5th and 6th miles	" 7,000
Total for Drainage Cuts ...	Rs. 32,795

For the whole drainage then the cost will be as follows:—

	Rs.
Two inlets in 1st mile	4,000
Syphon drains	1,19,000
Drainage Cuts	32,795
Grand Total ... Rs.	1,55,795

The main canal ends at 11½ miles from the head, in 11 feet cutting.

E.—Patna Branch and its subordinate lines.

After quitting the main canal the Patna Branch will begin to give out water for irrigation on the surface of the country at 12½ miles from the main canal head. It continues on the water-shed between the Burwai Nala and the Soane, and beyond the Burwai, still at very satisfactory levels as far as the 29th mile and over a country apparently of good stiff soil. From the 29th to the 49th mile of its course the country is uneven and the soil more sandy. The local drainage appears to be complicated by depressions arising apparently from old beds of the Soane, and it will require a detailed survey to settle precisely the proper line to take for the canal, and the drainage cuts that will be wanted. No difficulty is however to be apprehended, and the expense in drainage cuts will probably be more than covered by the 5 per cent. allowed for contingencies in the estimate of excavation.

The Soane appears at one time to have passed inside the Towns of Daoodnugger and Ahmedgunj, or between them, or rather between their sites; for the towns were not at that time in existence.

On the east bank our examination of the Soane floods had not extended below Sydabad, when the mutiny of 1857 stopped proceedings. At Sydabad there is an old channel of the Soane by which it is said the river formerly entered the Ganges near Patna. Soane flood water crosses the country by this, but the extent and course of the flood was not ascertained.

Above Sydabad the only points where the floods pass are near Ibrahimpoor Sakree, and Ehyapoor, and again at Mohābălipoor (on the 59th and 63rd miles of the canal), where a small spill over the bank takes place and the water flows to the Poonpoon. The spill appears to be so slight that it may be safely embanked off. The canal should be carried on the water-shed within half a mile of the Soane bank, and the spoil bank all thrown on the Soane side. But if the floods below Sydabad prove very formidable, it will be better to make the Paleegunj Branch the main line, and carry the navigation down the Poonpoon to the Ganges, leaving the irrigation of the tract from Mohābălipoor to Sydabad, and beyond, to be provided for by small channels which the floods may be allowed to pass over without doing serious damage.

F.—Tikaree Branch, with its subordinate branches.

This canal is to carry 400 cubic feet per second with a width on floor of 26 feet, and depth of water 4 feet, and divides into numerous branches to irrigate the country in the angle between the Poonpoon and Grand Trunk Road as far as Tikaree. This part of the project has been less investigated than any of the others.

The country here is perhaps more in need of irrigation than that to be watered by the other branches, but the water has to be carried across so much formidable drainage that it will hardly be a paying line. Still I think it ought not to be omitted as an essential part of a scheme of which the object is to utilize as far as possible the waters of the Soane.

I have only information enough to enable me to lay down the principles on which I propose to lay out the works. The exact line to be followed will possibly vary greatly from what has been sketched in Plate III.

With the Main Tikaree Branch the object is to carry the water as far as possible to the westward, avoiding as much as we can loss of level, so that we may extend the benefits of the irrigation to the greatest possible portions of the tract between the rivers which fall into the Poonpoon and Morhur. To carry out this object it will be necessary to carry the main line without a fall, or as nearly as possible without a fall, from its head to the country due south of Tikaree, keeping as far as possible to the south without getting into deep cutting. The deep cutting in the centre of the *Doabs** crossed should be avoided by curving the canal to the north in passing the high ground, and again recurving to the south for the passage of the rivers. It may be necessary to give a less declivity to the Main Tikaree Branch than has been allowed in the Table; in order to bring a sufficiently large area under its command for irrigation, I should not hesitate to reduce it to 1 foot in the mile, which indeed the Sketch in Plate III. assumes to have been done.

The drainage to be crossed will consist of :—

The Poonpoon, about	200	feet wide.
Bootana	600	"
Uddree	150	"
Tikaree	60	"
Madar	150	"
Dhawa	60	"
Neera	20	"

For the aqueducts for the Poonpoon and Bootana Rs. 1,000 per foot forward† of water-way, approaches and all works included, will probably be an outside estimate; for the other rivers Rs. 600 per foot forward will suffice. But of these latter rivers I have only single and rough Sections, so that the whole estimate will be subject

* *Doab,* literally *two waters,* a convenient word, of Persian origin, for the tract of country between two rivers.

† The cost of the great Solani Aqueduct on the Ganges Canal comes to about Rs. 3,600 per foot forward, about half being for the embankment across the valley. The width of masonry over all was 180 feet. For the Tikaree Branch 60 feet will be the outside width, with a liberal allowance for road-ways on both sides, and there is no valley to cross at the Bootana.

to much modification. I shall set down the cost of the drainage works thus :—

		Rs.
Passage of the Poonpoon	... ...	2,00,000
Ditto Bootana	... ...	6,0[illegible],000
Ditto Uddree	... ...	90,000
Ditto Tikaree	... ...	36,000
Ditto Madar	... ...	90,000
Ditto Dhawa	... ...	36,000
Ditto Neera	... ...	15,000

There will be nothing peculiar in the laying out of the minor channels except that the country has a rapid fall, which will require numerous Falls or Locks. But this expense may possibly be avoided to some extent by giving the canals a serpentine course.

SECTION X.—FALLS, LOCKS, AND BARRIER BRIDGES.

The question as to which is the best form of Fall for irrigating canals has for some years occupied the attention of Cana Engineers in Northern India. The object of these works is tol get rid of a greater declivity of bed than it is expedient to allow in mere earthen channels, and it is sought to be attained by giving at intervals sudden falls protected by masonry, between which the simple earthen bed may preserve its proper slope. Three forms have been used in Northern India (and I believe also in Italy); first, the Ogee Fall, which is in use on the Jumna and Ganges Canals, and in a few cases on the Baree Doab Canal; second, the Drop Fall with or without a grating, and third, the Rapid, both of which are in use on the Baree Doab Canal. Sections of these three forms are given in Plate XIV.

In choosing the Ogee Fall for the Ganges Canal in preference to the Drop, Sir Proby Cautley observes :—

"I have from the first considered this question of perpendicular fall, under every imaginable point of view that offered itself, and I am fully impressed with the conviction, that in dealing with large masses of water, as we are proposing to do in the Ganges Canal works, under the circumstances of the soil and slope of the

bed; under the nature of the material with which we are forced to construct our buildings; and under a continuous flow of water equal to that which I have noted above, the perpendicular fall would be inapplicable; it would, in my opinion, be expensive and dangerous; and further than this, I cannot imagine that floorings made of brick would for any length of time be able to withstand the concussion, and the violent action of the water in the reservoir.

"Although discussing a principle, I have used the expression expense in the foregoing paragraph. This item would in many of our falls have been one attendant, in an exorbitant degree, on the adoption of the perpendicular and reservoir plan. The reservoir, to be efficient, must have been equal in depth to the height of the fall, or at least equal to one-half of it; its sides and floorings must have been built of the most massive proportions, and the work, supposing that brick is used, must have been most carefully executed. In cases such as the Puttri Falls, where the foundations were actually laid 21½ feet below the surface of springs, and where I was obliged to sacrifice the reservoir at the foot of the drop in the lock chamber, in consequence of the extreme difficulties that we had to contend against, the cost of perpendicular falls, with their necessarily attendant reservoirs, would have been enormous."

The Ogee Falls have not, however, completely answered Sir Proby's expectations. It would seem in fact that the action of the short Ogee in the case of such a body of water (6,750 cubic feet per second) was much the same as that of a perpendicular drop; at least the wear and tear in the case of the Ganges Canal Falls has been great, and the other two forms are much preferred on the Baree Doab Canal. Possibly a more flat ogee, such as those drawn in Plate XIV., would have answered.

The form of Drop Fall used on the Baree Doab Canal was adopted by Captain Dyas, the Director of Canals in the Punjab, after experiments made on the old Huslee Canal, carrying 250 cubic feet of water per second; and I understand that they have been found to answer perfectly on the Baree Doab Canal, which is to carry 3,000 cubic feet per second. The full supply of water has not as yet been admitted; but no apprehensions are entertained of

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the plan not answering with the full discharge. I extract below Captain Dyas's remarks on this subject in submitting the revised estimates for the Baree Doab Canal:—

"The experimental observations on falls, for instance, were not completed till last hot weather. Some of the details are yet wanting; but sufficient details for the estimate have been obtained. The result is found in the design for the Dhumraee Fall (No. 21), annexed to the revised estimate. I believe this description of fall will be found to be the cheapest yet adopted, both in original construction and in after repairs. With one exception all the falls are designed on this plan. It will be seen, from reference to the plan, that the water is made to fall vertically through a grating laid at a slope (here about 1 in 3), and that its action on the surface below is thus spread over as large an area as may be wished; *owing to the several filaments of water being separated by the bars, much air is carried down with the water, and the action below is reduced to a minimum.* The bars laid longitudinally (with the stream); at their lower ends, which rest on the crest of the fall, they are close together; and the upper end, they are about 0·2 apart. The teeth of comb give a good idea of the arrangement. It was my intention to have had iron bars, T shaped; but the cost was found to be rather heavy, and wooden bars have been substituted in the estimate. As these bars can with ease be shifted singly, and renewed as often as may be necessary, at a small expense, I do not see any objection to the use of wood here, although ordinarily it is objectionable in a permanent work. From the slope of the bars, and the way in which they are laid, the spaces between them widening both in the direction of their length and at right angles to that direction, it is evident that small substances rolled down by the current will have no tendency to stick between the bars. As the substances are forced onwards by the current, they find a gradually increasing space to pass through, and practically, they either do pass through, or they are rolled over the top of the grating, which is a foot or so below the full supply level; a path-way is arranged right across the fall, and close in front of the grating, so that any rubbish which may accumulate on the grating, when the water in the canal is lower than the full supply level, may be raked off. But

supposing that there were no one at hand to rake it off, and that the grating become choked, the water would merely rise until it could pour over the top of the grating, and the rubbish would be swept over with it.

" 43.—This kind of fall is intended for complete falls, in which the height of the fall is not less than the depth of water in the canal, although it may be applied to 'incomplete' falls as well. For incomplete falls some experiments have been made by Lieut. Crofton on a syphon fall proposed by him, the water being compelled to pass down under a beam of wood or masonry, by which means its velocity is much checked, and the action confined to a short length of channel, which, being properly protected by masonry flooring and sides, delivering the water to the earthen channel at a moderate velocity.

"44.—It is evident that no accidents can happen from timber or boats going over these falls, and that the velocity of the water in its approach to the falls is not at all accelerated. Lock channels may, therefore, be shortened with safety. Repairs also can be executed with facility, as the length of the fall is divided into a number of openings of 10 feet each, and any one of these openings may be shut off while the canal is running.

" 45.—The grating arrangement occurred to me while experimenting on a vertical fall (No. 17) built without a grating; the action in the water below, concentrated in a small space of about a foot wide along the whole length of the fall, appeared to me dangerous, notwithstanding the interposition of body of water 8 feet deep between the falling water and the flooring, and I have, within the last few days, heard from the Superintendent of the Dhoon Canals, that the cutting action of the water on the side walls of the vertical falls built in those canals has done much damage."

The last form, and which has also answered well, is that of a Rapid, proposed originally by Lieut. Crofton, Superintendent of the Baree Doab Canal. It consists (as finally approved) of a slope of 15 base to 1 height, on which, and for an equal distance below, boulders are packed dry between dwarf walls, also of boulders, but cemented, of which the top is level with the bed of the canal. These walls are about 40 feet apart, both longitudinally

and across stream. Although the plan has answered perfectly, it is an essential condition to its being practicable that there should be an abundant supply of boulders within a short distance, so as to make the material cheap at the works.

I could not adopt this latter plan as a general one, because the Soane Canals will have the greater number of their falls too far from the hills to be within reach of cheap stone. This plan might be adopted at Kuroundea, and at a few other places, in preference to the Drop Falls I have proposed.

It was my intention to have adopted the Baree Doab Canal design of Drop Fall exactly; but the great number of falls required for the Soane Canals, and the comparatively small body of water to be dealt with, induced me to seek for a cheaper plan, and left me at liberty to adopt one having less massiveness than would have been necessary with larger bodies of water.

Fortunately the Soane Canals will require no falls on the main lines. The largest channel (Upper Sasseram Branch) upon which falls will be required is to carry 1,090 cubic feet per second, and as we may depend upon the waste weirs of the double locks to carry off 440 cubic feet of this, there remain only 650 cubic feet per second to be dealt with on the main fall. There will be larger bodies of water to deal with on the escape lines of the main canals, but these will only flow occasionally, and will consequently require much less precaution than the constantly flowing stream of a large canal.

I have therefore dispensed with the first set of separate chambers of 10 feet wide, given in the Baree Doab Canal plan, and have admitted the cascade at once into the large open bason, which I have extended in size and provided a deeper cushion of water to receive fall; see Plate XIV. Also by widening the canal channel considerably above the fall, the depth of water over the sill will be reduced to 2 feet, making the actual fall only 4 feet from surface to surface. Under these circumstances I have also dispensed with the grating. Our upper falls will be of rubble stone masonry, and if the action of the water on this, or on the brick-work lower down the canals, be found severe, it will be easy to replace the facing of the revetment under the fall by

cut-stone work as a repair, using the water carriage of the canal to bring the material cheaply to site. The cost of this arrangement for a fall of 60 feet water way will be about Rs. 20,000; see Estimate No. 10, and the Table at page cii. of the Appendix.

I have placed the bridge for cross communication on the tail of the fall instead of at the head, which is in itself a saving of expense. In this, and in the non-division of the bason, I give up the power of closing the fall partially, by stopping one or more arches of the bridge in case of repairs being urgently required; but this is not of great importance, as even in the case of the largest fall we can pass more than half of the supply of the canal over the waste weirs of the locks, leaving the main fall dry for repairs, provided there be an arrangement for totally closing the main channel at the lock channel heads.

For this purpose I have adopted barrier bridges of masonry; see Plate XVI. On the subject of closing the entrance to the main canal above the falls, Sir P. Cautley writes:—

"It was very clear that to consider the main line as a navigable one, with the prospect of boats or rafts being brought in contact with the falls, was unreasonable. It mattered little whether through carelessness or accident boats were overwhelmed in these cataracts.

"Catastrophes of this sort were to be avoided. The notorious apathy of native boatmen was well known; the carelessness and neglect of Establishments were contingencies of too frequent occurrence to be treated with indifference; and the possibility of craft passing the navigable head, and proceeding onwards towards the falls, was obviously a matter to be guarded against. It was a case in which no half measures would answer, and one in which the prevention to danger ought to be so certain that no reasonable contingency should be likely to defeat it."

Sir Proby proposed to use bridges of boats attached to the masonry heads of the lock channels.

In practice, however, on the Ganges Canal no barrier has been yet found necessary, and no accidents have happened. The simple masonry barrier bridge which I have designed, however, will cost little, and affords a convenient means of stopping the flow of water over the fall. The cost of a bridge of 30 feet water-way,

such as is suitable above the 60-feet fall, is about Rs. 3,700, including the masonry work for the lock channel heads.

For the small channels which are not to be used for navigation except for the smallest boats, a barrier above the falls will be unnecessary. In those narrow channels it would be hardly possible for a boat to be carried over. It would stick at the sill of the fall. The water-way of the fall may, however, in these cases be closed by planks fitted to groves above the fall.

The plan of Lock is adopted almost without alteration (except as regards foundations) from the Ganges Canal designs. Indeed I have hardly made as much reduction as I might have done to suit the smaller depth of water to be dealt with on the Soane Canals. The lock channels on the Ganges Canal are 15 feet wide at bottom, and leave the main canal 4,500 feet above the falls, rejoining 4,000 feet below them.

To pass now from the designs to general arrangement of the works for overcoming the excess of declivity on the canal lines without interrupting navigation, I must first remark I am informed by Colonel Baird Smith that already the traffic on the Ganges Canal feels the want of double locks, and wider channels to pass conveniently the up and down traffic. I therefore at first proposed to give two locks with separate channels right and left of the main canal, as shown in the diagram to Plate XV. This would probably be a more convenient arrangement for the traffic than to place both locks on a single but wider channel.

Considerations of economy have however induced me to adopt the latter arrangement. Where it is an object to pass as much water as possible by the waste channels, I adopt a construction of two locks in the centre with a waste channel on each side: this is a double lock with double waste channel. Where the discharge of water is less, two locks with a single waste channel between them may be used: this is a double lock with single waste channel.

This change of arrangement will require a slight alteration in the design for the barrier bridge, enlarging the masonry passage for the lock channel head on one side, and reducing it to form a Distributary channel head on the other.

It will be seen in Estimate No. 11, A, B, and C, that the cost of these arrangements severally is—

Single lock Rs. 23,500 to 31,800; on the average 27,500.

Double lock with single waste channel Rs. 32,000 to 44,300; on the average 38,000.

Double lock with double waste channel Rs. 37,800 to 51,400; on the average 44,600.

The cost of a lock channel to unite the single lock with the main canal, as in the diagram in Plate XV., is about Rs. 7,000; and it will be easily deduced that a channel 20 feet wide on the floor, for the double locks, would cost Rs. 9,000 at the same rate.

(It will be well to keep the bed of the lock channel at a level from the barrier bridge to the lock, and to let it have the fall of the main canal from below the lock to the junction.)

The waste channels of the locks will, as already said, carry 220 cubic feet per second each over the weir, if taken at 3½ feet depth or kept at that by means of the planks. None of the large locks will discharge less than that when the planks are open. Hence we may always be able to dispose of that quantity of water by means of each waste channel.

Wherever we have a double waste channel, therefore, we shall only have to provide at the falls for the difference between a flow of 440 cubic feet per second and that of the canal. The only canals (excepting the main one, on which no locks on falls are required) which have a discharge of more than 440 cubic feet per second are—

The Sasseram Branch, upper		1,091	cubic feet	per second
The Buxar Branch, upper		669	ditto	ditto
The Arrah Branch, upper reach		877	ditto	ditto
Ditto	second ditto	576	ditto	ditto
The Patna Branch, first part		738	ditto	ditto
Ditto	second ditto	659	ditto	ditto
Ditto	third ditto	532	ditto	ditto

The excess above 440 feet per second in the 4th and 7th of these may easily be made to pass over the waste weirs of the lock

channels with 4½ feet depth of water, or by giving, if thought desirable, a slight increase of width to the waste weir. For these channels therefore no separate lock channel and no fall will be requisite; the locks may be placed in the canal itself. But for the other five branches there will be required separate falls, as follows:—

Sasseram Branch, fall of 60 feet water-way
Arrah upper ditto, ditto 50
Patna upper ditto, ditto 40
Buxar, and 2nd portion of Patna Branches, each 30.

The cost of the whole works, for these seven branches, at each fall would thus be—

Sasseram Branch.

Barrier Bridge of five spans	Rs.	3,700
Fall 60 feet water-way	"	20,000
Double lock with double waste channel..	"	44,600
Navigable channel for ditto	"	9,000
	Total Rs.	77,300

Arrah Branch, first portion.

Barrier Bridge of four spans	Rs.	3,500
Fall 40 feet water-way	"	15,500
Locks with navigable channel, as above	"	53,600
	Total Rs.	72,600

Patna Branch, first portion.

Barrier Bridge of four spans	Rs.	3,500
Fall 40 feet water-way	"	11,500
Locks and channel as above	"	53,600
	Total Rs.	68,600

Patna Branch, second portion, and Buxar Branch, upper portion.

Barrier Bridge of three spans ...	...	Rs.	3,300
Fall 30 feet water-way ...	... ...	"	7,500
Locks and channel, as above ...	...	"	53,600
		Total Rs.	64,400

while for the third portion of the Patna, and second portion of the Arrah Branches the expense at each fall would be for the locks only, or Rs. 44,600.

The expense will be the same for the other branches on the main navigable lines where the discharge is not less than 300 cubic feet per second.

For the channels on the main navigable lines where the discharge is less than 300 cubic feet per second, we may adopt the cheaper arrangement of a single waste channel between two locks, at a cost, on the average, of Rs 38,000.

But besides the main navigation lines there will be many other branches, down to the VIIIth Class channels inclusive, in which, the full supply depth of water exceeding 2½ feet, some sort of navigation will be practicable. It would be out of the question to allow for these locks on the same expensive scale as those above given, but it would be a pity to suffer the navigation to be lost for want of locks at the numerous falls it will be necessary to give. For these branches I have proposed a lock of 60 × 10 feet chamber, with a waste channel from 10 to 4 feet wide, of which the cost will be, on the average, about Rs. 6,500. (See Estimate No. 11 E, page cxvi. of the Appendix.) I may remark here that the only branch not on the four main navigable lines of which the discharge could not be carried off by such a lock is the upper part of the Tikaree Branch, which is to be laid out so as not to require any fall.

I have not yet mentioned the Corn Mills which it is intended to place at each Lock and Fall. They are designed after the plan of those on the Ganges Canal, as drawn attached to the locks in Plate XV. The plan is a native one, which was adopted by Sir Proby Cautley as cheap and simple, and answering sufficiently well in

cases where there is an ample supply of water, and where the fall is 3 feet or more. The machinery has been drawn and described in detail by Sir Proby in the Journal of the Asiatic Society of Bengal for 1833, and in his recent Report.

Two mills with six pairs of stones will cost by the Estimate No. 11 D, Rs. 2,150. A single mill of the same description with three pairs of stones attached to a fall or lock, would cost about Rs. 1,300. I have proposed to add two mills to each of the large locks, 120 × 16 feet, and one to each of the small locks, and to each of the falls without locks on the minor channels.

Before leaving the subject of locks and falls, it will be proper to show how much the cost of the works is enhanced by the provision of the former in addition to the latter; that is, to state the cost properly chargeable to the navigation.

Canal Branches.	If falls only were provided.		Total charge for locks and falls.	Excess of cost due to navigation.
	Water-way.	Cost Rs.	Rs.	Rs.
Sasseram Branch	100	35,000	77,300	42,300
Arrah Branch, 1st	80	27,000	72,600	45,600
Patna ditto	70	23,000	68,600	45,600
Patna branch, 2nd part, &c. ...	60	20,000	64,400	44,400
Main navigable channels of 580 to 300 feet discharged	40	15,500	44,600	29,900
Ditto below 300 ditto	30	7,500	3,8000	3,0500
Ditto where only one lock is required	25	5,500	27,500	22,000
Ordinary lines VIIth Class ...	25	5,500	6,500	1,000
Ditto VIIIth Class ...	20	4,000	6,500	2,500

The sums in the last column only will be entered as chargeable to navigation in the estimate, and the rest as part of the necessary charge for the canal as a work of irrigation alone.

For the IXth and Xth Classes of channel the falls will be of 10 and 7 feet water-way, costing Rs. 2,000 and 1,000 respectively.

Section XI.—Bridges and Branch Heads.

All the bridges on the four main navigable lines of canal are designed with 13 feet head-way for boats, and a tow-path of 6 feet wide on each side, within the arch of the bridge. These provisions render the bridges more expensive than they otherwise

would be, especially the former, which adds greatly to the cost of the wing walls and earthen ramps of approach.

The Distributary channel heads, and drainage inlets attached with so much elegance of design by Sir Proby Cautley to the bridges in his plans for the Ganges Canal, and which have been followed in the Baree Doab Canal, I have not adopted. They have, I believe, been found to tend to inconvenience in practice. It is now deemed better to have detached heads for the Distributaries, which leaves the Canal Engineer more at liberty to choose for them the best positions, and it is found better to keep the drainage as much as possible out of the canal. I have therefore deviated from the established designs in these matters, under the sanction of Colonel Baird Smith's judgment.

The following Table shows the sizes and cost of the bridges, for further details regarding which I refer to Plates XVII. and XX. and to Estimates Nos. 13 A to G in the Appendix.

Denomination.	Spans.		Cost of Bridge.	Remarks.
	No.	Width.	Rs.	
For deep cutting Western Canal	5	33	26,500	These designs are adapted to navigation with 13 feet head-way and two 6 feet tow-paths.
Ditto ditto Eastern ditto ...	4	37	23,500	
Class I	3	33	19,000	
Class II	2	37	16,000	
Class III	2	33	14,000	
Class IV...	2	28	10,000	
Class V	1	44	9,000	
Class VI...	1	37	8,000	
Class VII	1	28	6,000	
Class VIII	1	22	2,300	
Class IX...	1	16	1,700	
Class X	1	10	1,400	

The width of road-way given to these bridges is only 16 feet for ordinary village communication. For district roads I allow 25 per cent., and for the trunk road 50 per cent. additional cost to provide greater width.

Lines of steps have been added both above and below the bridge as a protection to the banks.

The water-way allowed is exactly the same area of section as on the canal with a full supply.

For the smaller channels (Classes Nos. IX. and X.) when the depth of water is less than two feet, I do not allow any bridges for mere village communication, but provide Metalled Fords such as will be found described in the Estimate for the Distributary Channels, No. 15 in the Appendix. The cost as will be seen by inspection will be Rs. 120 for the Channel Class X. and Rs. 150 for Class IX.

The material for the bridges must be undressed stone or brick, according to locality; but I have allowed a little cut-stone work for the ornamental parts of those bridges which are built of stone. The rise of the arch is universally ⅛th of the span, which will require care in turning the arch when of undressed stone. If it be found difficult to get the arches turned in rubble, brick may be substituted. But as the sandstone quarries well, and the masons have been accustomed to build large rubble arches on the Grand Trunk Road, I do not apprehend any great difficulty. The additional cost of making the arches of cut-stone would not be very heavy,—about Rs. 500 for each arch of the larger bridges; but the delay in getting the stone cut would be great.

The centerings of the arches should be constructed of earth, as explained in the following extract:—

"The arches of all the bridges extending from the 47th to the "110th mile were built on centerings of earth only; * * *

"With the exception of eight bridges at the lower extremity "of the line on which this species of centering was used, the canal "channel had, previously to the construction of the arches, been "entirely cleaned out and excavated; this was rendered necessary "from the sandy nature of the soil, which did not admit of "rectangular sided excavations for piers and abutments; on the "contrary, to prevent accidents from the subsidence of the sides, "it was a matter of the utmost expediency to excavate in long "slopes; and during the progress of the building of either the "foundations of the piers and abutments, or of the curtain walls "lying intermediately to carry on a gradual process of falling in,

"the level of each day's work in masonry being met by a corres-"ponding level in the replacement of the earth. * * * "The course of proceeding in all the abovementioned cases was "as follows:—To complete the excavation of the canal, to finish "the substructure of the bridge in all its parts (with exception to "the bay floorings) up to the level of the top of the impost blocks; "to fill the bays with earth, as shown in the preceding diagram; "to form the upper part of the surface in the desired curve, and "upon it to build the arch." Sir P. Cautley's Report on the Ganges Canal, vol. II., page 202.

The result was great economy. A specimen is given, page 236, of the rates per 100 cubic feet of brick work—Plain work Rs. 11-0-8; Arch work Rs. 14-9-0. This was in a large division of bridges. There was some settlement, and cracking near the haunches, but it was slight, and quite immaterial compared with the economy of the method.

The comparatively greater height of the bridges for the Soane Canals will require a comparatively higher rate for arching; but I believe Rs. 25 against 15 for ordinary masonry will prove ample.

There being in these estimates no provision for letting into the canal the drainage arrested by the embankments of approach to the bridges, it will be necessary to provide culverts for the purpose of passing it forward. These are included in Estimates No. 13 H and K. Two of the 4-feet culverts at Rs. 470 each, or Rs. 940 per bridge, will be used for each of the bridges down to Class VII., and the smaller culverts at Rs. 200 for each culvert, or Rs. 400 per bridge for the bridges of smaller size.

Having decided on providing tow-paths within the arches to all the ordinary bridges, I have not thought it necessary to make exceptions of those to be used as Regulators at the Branch Heads. These bridges are designed exactly the same as the others, with the addition of a redan-shaped cut-water of steps between them, to part the water towards the two channels, and an increased width of flooring *below, to receive the scour due to the application in part of the regulating stop boards.*

The regulating apparatus itself has been changed from the ordinary design to suit the bridges with tow-paths. For these, drop gates, though they may be used, seemed to me inconvenient, and I have proposed perpendicular stop planks resting against beams. The whole arrangement is shown in Plate XVIII.

An escape is allowed above each bifurcation, of sufficient capacity to lay both the lower channels dry. Where the object is to diminish the supply of water in both, therefore, it will be unnecessary to do more than open the requisite number of bays of the escape bridge. But when it is desired to keep up the whole supply in one channel, and reduce it, or altogether to cut it off, in the other, it will be necessary to drop the sill beam in by the grooves, using the blocks and tackling (in the deep channels) for the end towards the pier, and afterwards to fix the upper beam in its seat by the same means. After this, using the upper beam as a bridge, the stop boards will be applied by hand, to such extent as may be desired.

The plan will not be so expeditious as that of the drop gates and windlasses. But it will, I believe, provide in a simple way all that is wanted. The use of a few long drop boards, such as could be let down from the parapet of the bridge, would enable us to partially close the openings without stopping navigation. The same object might be attained by the use of a frame for supporting a shorter upper beam in the water-way.

Section XII.—Distributaries.

It has become a principle in managing the irrigation canals in Northern India, that no water shall be taken by the cultivators directly from the canals, but that they shall be supplied only from Main Distributary water-courses called by the natives Rajbuhas. These Rajbuhas carry from 80 to 5 cubic feet per second according to the features, extent, and position of the land they are intended to irrigate, and from these are drawn the village water-courses for the immediate use of the cultivators. In this system we may, as Sir P. Cautley remarks, consider the canal as answering to the reservoir or supply channel in the water-supply of towns; the *Rajbuhas or Distributaries as the "Mains," and the village water*-courses as the "Service" channels.

The village water-courses are always constructed at the expense of, and by the cultivators; and the waste of water that arose from their ignorant attempts to carry channels for long distancess was one of the inconveniences that led to the adoption of the Rajbuha system, in which these Main Distributaries are laid out at the best levels, and constructed by the Canal Engineers. The expense used formerly to be advanced originally by the Government, and subsequently recovered by instalments from the cultivators. Latterly, however, it has been decided that the Government shall bear all the expense of construction and repair of these works, charging an enhanced rate of water-rent to cover it. The rate of increase proposed and sanctioned is Rs. 100 per cubic foot per second of the canal discharge, but of this I shall say more when I come to treat of the returns derivable from the works.

Now in applying this system to the projected Soane Canals, a difficulty at once presents itself in the already minute sub-division of channels. Many of these are already of less size than some of the Rajbuhas of the Ganges Canal. When shall the canal be considered as being merged in the Rajbuha?

After consulting Colonel Baird Smith on the subject I have taken the following rules for my guidance:—

I. No village water-course shall be drawn direct from any canal of which the discharge is more than 70 cubic feet per second.

II. Rajbuhas shall be provided, in addition to the smaller Canal channels, to such extent as shall be necessary to bring the water within 3 miles of every part of the country to be irrigated; so that no village water-course need be made more than 3 miles long at the most.

The cost of the Rajbuhas on the Ganges Canal is about Rs. 1,000 per mile. I have made up an estimate, from examples of works, intended to be the average of what will be required, which comes to about Rs. 1,300 per mile, including the cost of land. In this I provide, by Colonel Baird Smith's advice, two heads to each Rajbuha. The silt deposits which take place in these works, especially when at a low slope of bed, do not extend for more than a mile down the channel, and by providing a double head and

double channel in the first mile, we have the means of carrying on the irrigation, without interruption from this cause.

Plate XXI. is intended to illustrate the system of Rajbuhas or distributary channels. Figure 1 is a diagram showing the mode of laying out the channels. A and B show the methods ordinarily used in Northern India, where the slope of the country seldom admits of the waters of the Rajbuha being returned into the canal. C and D show methods by which this latter desideratum may be obtained under the slope of the plains of Shahabad and Behar. But the Engineer must be careful not to attempt to be too systematic, but to be guided by his own ingenuity and the nature of the ground in each case.

It appears to me that it will be found a good principle in administration to keep each Rajbuha distinct from every other (when it can be managed), from its head to its terminus, so that the expenditure of water on each Distributary may be separately ascertained and checked; being measured both on its issue at the head and on its return at the tail fall into the canal.

C, in the diagram, gives an example how this may be done in a case where the canal is too far in soil to afford water at a proper level to irrigate close to its banks. The Rajbuha gets to a proper level for irrigation at b, b^2, &c., passing there over a syphon or fall conveying the returning upper Rajbuha, which from loss of level in the crossing does not irrigate again till it comes to d, d^2, &c., when it passes over the Rajbuha next but one below it, and irrigates the land close to the canal bank, ere it returns by a drop into the canal. An arrangement of this kind could only be effected with a very good fall of country.

The remainder of Plate XXI. hardly requires explanation, except in regard to the Rajbuha-heads and village water-course heads, which are on the plan of the Italian Modules for measuring water. The system is to reckon the water by the discharge under a given head, which is known by the ordinary hydraulic rules, either (1) when the discharge takes place freely into the air, or (2) when it is simply a descent from a upper to a lower level.

My plan of module is adapted to the latter method. In both cases the front sluice board is used to admit such a supply as shall just keep the level of the water in the interior chamber at the mark denoting the desired head of supply. But on the village water-course heads it would be impossible to supervise the working of the head sluice board. It can only be used to shut off the supply when the water is not required. The level of these water-course heads must be so placed that when the intended supply of water is passing down the Rajbuha, every village water-course may just have its proper supply, as contracted for. The regulation must be attempted only at the Rajbuha head, and the Government will lose a portion of the tail surplus, and the other villages or cultivators gain it, when one or more villages or cultivators let their modules remain closed.

XIII.—Terminal Works.

The Terminal works of all the escape channels and of all canals, except of the chief navigable lines, will be simple falls like the falls on the course of the channels themselves, dropping them to the level of the natural water-course into which they are to discharge their surplus waters.

But the chief navigable lines will end each in a double series of locks connecting them with the dry season level of the Ganges. The highest rise of the Ganges at Benares is about 41 feet above the dry season stream. But this height it attains only once in 10 or 20 years. However, it will be seen by the Sections to Plate II. that a descent of 30 or 40 feet will in all probability have to be accomplished. I have taken no steps as yet to obtain data for these descents, and have therefore prepared no design or estimate.

I have only to suggest that the descents near Benares might perhaps with advantage fall into the Jhurgoo, so as to avoid crossing the Railway. That at Chowsa may certainly be taken into the Kurrumnassa, which, with the addition of a supply of 150 cubic feet per second, would be quite navigable. That near Arrah I would propose not to attempt to carry to the Ganges at all, unless great inducement should offer, but to drop into one of the nalas near Arrah, south of the Railway, and render that navigable as far as

the town. That near Patna should be carried into the Ganges if possible; but if the difficulties of crossing the Soane floods prove too great, it might be taken into the Poonpoon, and, if necessary, works constructed to make that river navigable in the dry season.

It is necessary, however, to set down an adequate sum for these terminal works in an estimate of the cost of the whole project, and for this my only guide is the Ganges Canal estimate of 1850. The terminal works at Cwnpoor are there set down at Rs. 1,60,860, and those at Etawa at Rs. 86,724. I believe the estimate for the Cawnpoor works was greatly exceeded, partly from the addition of ornamental works, and partly from difficulties in the foundations. I think it will not be safe to estimate the cost of the terminal works of the Soane Canal navigable lines at less than 2½ lakhs each, except the Arrah works, for which 1½ lakhs will suffice. At Patna it will be necessary to add an additional lakh for compensation for buildings which will have to be removed. This will be in all Rs. 10,00,000.

SECTION XIV.—RATES AND COST OF WORKS.

The rates for masonry and brick-work in Shahabad and Behar have undergone considerable changes since the Railway works were put in hand, and since the occurrence of the mutiny, so that it is not very easy to determine, even setting aside the disturbing effect on the market of commencing large works like those now under consideration, what the actual prevailing rate now is.

The greater part of the drainage works west of the Soane, spoken of in the 14th paragraph of the Report of 1853, were completed at rates on the average below Rs. 8 per 100 cubic feet for rubble stone masonry. The earth-work cost Rs. 1-3-0 per 1,000 cubic feet. At a later date, just before the mutinies, the viaducts on the Grand Trunk Road, for the passage of the floods of the Doorgowtee, were executed at a rate under Rs. 10 per 100 cubic feet. The rates for brick-work in the neighbourhood of Dinapore and Patna were at the same period generally under Rs. 9 per 100 cubic feet.

In 1854 or 1855 the rates allowed to the Railway Contractors were,—

For ordinary brick-work, Rs. 22 per 100 cubic feet.

For brick-work in the larger bridges, Rs. 24 per 100 cubic feet.

For earth-work in ordinary embankments, Rs. 4 per 1,000 cubic feet.

For earth-work in excavation of tanks under 10 feet, Rs. 4¾ per 1,000 cubic feet.

The rates for the Government works in 1861, are about as follows :—

Rubble masonry on the Grand Trunk Road, Rs. 13 to 15 per 100 cubic feet.

Brick-work in the Dinapoor Division, Rs. 12 to 16 per 100 cubic feet.

Earth-work, Rs. 1½ to 2 per 1,000 cubic feet in ordinary embankments of roads.

I have assumed the average rate of Rs. 15 per 100 cubic feet for masonry and brick-work, including pointing or plastering. For earth-work I have taken the rates at Rs. 2 to 2½ per 1,000 cubic feet for ordinary excavation, allowing Rs. 3 or 4 for very deep cutting, and as much as Rs. 6 where baling may be required in foundations of works.

Wood-work is expensive in Shahabad and Behar. No large timber is to be had south of the Ganges in that neighbourhood, and for all the squared timber work we must depend on the markets of Benares, Ghazeepoor, Revelgunj and Patna, for sal wood floated down the Goomtee, Gogra and Gunduck from the foot of the Himalaya. I have usually allowed Rs. 3 per cubic foot for the finished wood-work. But in the case of lock gates, &c., I have allowed Rs. 5, taking the work solid, so as to cover cost of gearing and iron-work.

These rates, however, I give only as the rates which are likely to suffice independently of the effect upon the market of the execution of large works vigorously carried on in the districts. The effect of this is very marked in most cases, but it is difficult to estimate beforehand.

It will appear strange at first that the labour market in India should be so easily affected, where, above all other countries, we are accustomed to consider labour to be so abundant and cheap. But a little examination of the state of things will show that this is no more than was to be expected.

There is always a large proportion of the population of every merely agricultural village absolutely idle during almost the whole year. Except at harvest time, there is nothing like employment for the whole population. A few of the young men go out to seek employment at a distance, but the large proportion of the population are idle, unless work is absolutely brought to their doors. Then they will work on very low wages. I have stated in paragraph 12 of my Report of 1855 (Appendix, page xviii.) what the wages are for ordinary agricultural labour. For the Government works the usual wages are, per diem—

	Rs.	A.	P.
A beldar (able-bodied labourer) ..	0	1	6 or $2\frac{1}{4}$ pence.
A coolie or ordinary labourer ..	0	1	3 or $1\frac{7}{8}$ "
A woman coolie	0	1	0 or $1\frac{1}{2}$ "
A boy	0	0	9 or $0\frac{3}{4}$ to $1\frac{1}{8}$ penny.

The wages, however, are generally paid in pice of a varying value, of which from 78 to 82 usually go to the rupee, being from 0·292 to 0·307 of a penny each. Of these the beldar gets 6, the coolie 5, the woman 4, and boys 2 or 3.

These are the wages for which the people are willing to work within such a distance as to be able to return to their villages when the day's work is done. Small bodies of labourers may even be collected from a distance on these rates of pay, especially the Dhangurs, an aboriginal tribe from the south of Shahabad and Behar, who go to a considerable distance to work on low wages, and are very good workmen, though of small stature.

But the quantity of labour that can be collected on these wages is small, and the Head Works, where the greatest demand for labour will be, are on the borders of the hilly tracts of which the population does not exceed 3 per square mile.

It is difficult to say what increase of rate will be necessary to attract a sufficient body of workmen, but I should say not less than the usual rate for a beldar in the North-Western Provinces, of 2 annas or 8 pice per diem. This will be an increase of 33 per cent. on the existing wages for unskilled labour.

In skilled labour the classes most required are stone-cutters, mason, and brick-layers. The prevailing rates for these artificers near the Grand Trunk Road has been 2 annas a day.

Sasseram is a place of note for stone-cutters, who also act as quarry-men. They get some employment in the town and neighbourhood for building purposes, and can always make a livelihood by making hand mill-stones in the hills. But after all, the number of these men to be had in the neighbourhood is not great, and the Government works on the road have often been retarded for want of a sufficient number of them.

There is a corresponding proportion of masons near the hills, where stone-work is cheap in consequence of the proximity of the material. But when we get beyond the neighbourhood of the hills, stone or brick buildings are seldom seen. The villages are almost wholly of mud huts with thatched, or sometimes tiled roofs, and the village temple or mosque, with occasionally a resident Zemindar's house, are the only brick or stone-buildings to be seen, besides the small drains constructed from the Road and Ferry Funds on the district roads. One might travel 20 miles without seeing a brick-building in progress; and where there is so little brick-work or masonry going on, there are of course very few brick-layers or masons. In fact these men are only to be had from towns at a distance. They are more apt to leave their homes to seek work than the unskilled labourers, but some inducement must be offered; and as the rates of wages for good workmen on the Government works at Benares and Allahabad is 3 annas a day, we cannot expect to get the men at a distance for less, on the average of good and ordinary workmen.

On the whole it will, I think, be necessary to reckon upon a rise in the labour market of 33 per cent. in order to attract a sufficient number of labourers to carry on the work vigorously.

But it is not only in labour but in materials also that prices will be affected. In the first place fuel of all kinds, and other sorts of local produce, such as can be had in the neighbourhood of the works, will soon be exhausted, and the cost of carriage must be paid to procure them from a distance. Secondly, there will be, when we get beyond the reach of the hills, the difficulty of establishing brick manufacture on a large scale where it has never been tried on a large scale before, and where time cannot be afforded for the gradual developement of the manufacture. Speaking of the Nuggaram Aqueduct in the Godavery Delta, Sir A. Cotton says, "I determined to try if possible to get the work out of the reach of injury before the monsoon. In doing this we could not let any means slip on account of their cost; and when we meet with difficulties, such as those in the burning of bricks, as mentioned in Lieutenant Haig's Report, we could not stop to make experimental kilns of a few thousand bricks. We were obliged to continue making and burning them by lakhs without losing a day. As is so commonly the case the difficulty was one we least expected, having a most intelligent and able Overseer, who had been just before burning bricks with the most perfect success at other works. But both he and the native brick burners were entirely at fault. I have no doubt that the principal cause of our failures was the peculiar nature of the soil, which was that in which the tobacco is grown, and had never been used for bricks. It evidently requires a much higher heat than ordinary brick-earth. I mention this as a specimen of the obstacles we met with in pressing on the work."

Brick manufacture has always been one of our great difficulties in regard to large works in India, and we are fortunate in the Soane Canals in having so much of the heavy work within reach of the excellent building stone of the Kymore hills, and the granite west of the Poonpoon.

In order to allow for the whole effect of the rapid execution of these works on the local markets, both in labor and materials, I think it will be proper to add to the estimate, framed on the present prevailing rates, a proportion of 30 per cent. If the works are carried out gradually, perhaps something may be saved on this.

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But there are other causes which in the case of the large irrigation works in Northern India, have led to excesses in actual cost of construction over estimates framed beforehand, which it will be well to review before finally presenting the estimate for the Soane Canal works.

The first of these is the occurrence of sand. On both the Ganges and Bareė Doab Canals the expectations of the Engineers as to the cost of the works were disappointed by finding that the good soil on the surface extended to a depth of only 3 or 4 feet, and below that the whole of the soil was nearly pure sand over very large tracts of country. The cost of excavation is not affected by this, for although the width to be excavated is greater, the cost of excavation in sand is less. But it seriously affected the cost of the masonry works, in the increased massiveness of foundations it rendered necessary. To avoid all risk of having the estimates for the Soane Canals rendered insufficient from this cause, I have assumed that in half the works it will be necessary to adopt under-sunk foundations. This is not done under the supposition that such is at all likely to be the case, but as the most secure means of arriving at a "superior limit" to the probable expense.

Another cause of excess in the expenditure on the Ganges Canal was the order of Government, issued on sanitary grounds, that the surface of this canal should always be kept within soil. This my estimate provides for.

A third cause of excess over estimates is in the improvements and alterations dictated by local experience gained during the progress of the works. To refuse sanction to charges of this kind would be quite unreasonable. All we can do is to scrutinize proposals for such changes carefully, and see that none are admitted of which the origin is in mere fancy or caprice; and to administer blame where it appears to be deserved owing to want of care in the first estimate. But in India Engineers are peculiarly liable to be misled in many matters, from which the existence of similar works in the neighbourhood would save them in Europe. For instance we have there almost every river bridged above and below the intended crossing of a railway or canal, so that there can be no doubt as to the water-way to be given. But in India there is

generally no such guide, and the Engineer may examine and watch a river carefully for 9 years, and be surprised by a flood in the tenth, which far surpassed his highest expectations. From this cause arise frequent excesses over estimates. But I think the large provision for excess in the matter of foundations in the estimates for the Soane Canal works will cover the probable increase of expense from this source, considering that care has been taken always to over, rather than under estimate in doubtful cases.

I therefore conclude that an addition of 30 per cent. will cover the probable excesses over the estimates which are likely to arise from the effect of the execution of these canals on the local markets, and that the estimates are, in all other respects, ample.

I now present an abstract of the General Estimate in which I include 12½ per cent. on the cost of the works, for Establishments, including salaries, travelling allowances and contingent charges. This proportion is what it seems fair to allow with reference to the cost of the same branch of expenditure in other like works. The Estimates will be found in detail in Appendix B—

Head Works.

		Rs.	
Land		4,800	
Roads, Fences and Plantations... ...		3,800	
Temporary Dam	2,24,469		
Permanent ditto	11,29,269		
Plant for ditto	2,50,000		
		16,03,738	
Western Head Bridge	1,46,346		
Eastern ditto	34,462		
		1,80,808	
Western Lock Channel Head	1,33,973		
Eastern ditto	60,151		
		1,94,124	
Temporary Quarters ...	14,750		
Permanent ditto	62,000		
Workshops	50,000		
		1,26,750	
		21,14,020	
Establishment at 12½ per cent. ...		2,64,252	
		23,78,272	
Add 30 per cent. to cover probable rise of prices ...		6,34,206	30,12,478
Carried over			30,12,478

		Rs.	Rs.
Western Canal Main Channel.			
	Brought forward ...	...	30,12,478
Land ...	...	10,560	
Roads, Fences and Plantations...	...	7,860	
Excavation	...	5,73,381	
Drainage works, &c.	...	3,55,380	
Falls (on escape)	...	1,40,000	
Distributaries	...	13,000	
Bridges	...	1,29,000	
Accommodation for Establishment	...	15,925	
		12,45,106	
	Establishment at 12½ per cent....	1,55,638	
		14,00,744	
	Add 30 per cent. as before ...	3,73,532	
			17,74,276
Eastern Canal Main Channel.			
Land ...	...	9,600	
Roads, Fences and Plantations ...	...	6,600	
Excavation	...	4,46,709	
Drainage works, &c.	...	1,68,295	
Falls (on escape)	...	81,000	
Distributaries	...	13,000	
Bridges..	...	1,34,500	
Accommodation for Establishment	...	15,300	
		8,75,004	
	Establishment at 12½ per cent. ...	1,09,375	
		9,84,379	
	Add 30 per cent. as before ...	2,62,501	
			12,46,880
Arrah Branch.			
Land ...	...	49,394	
Roads, Fences and Plantations ...	...	44,852	
Excavation	...	5,09,813	
Works of drainage and regulation of supply	...	1,14,250	
Falls ...	...	3,72,000	
Distributaries	...	8,14,800	
Bridges and Fords ...	...	2,63,674	
Accommodation for Establishment	...	1,16,100	
Locks ...	...	7,36,400	
Mills ...	...	54,700	
		30,75,983	
	Establishment ...	3,84,498	
		34,60,481	
	Add 30 per cent, as before ...	9,22,795	
			43,83,276
	Carried over ...	...	104,16,910

		Rs.	Rs.
	Sasseram Branch.		
	Brought forward...	...	104,16,910
Land	...	54,452	
Roads, Fences and Plantations	...	54,818	
Excavation	...	5,84,166	
Works of drainage and regulation of supply	...	4,37,600	
Falls	...	4,09,000	
Distributaries	...	8,49,700	
Bridges and Fords	...	2,66,902	
Accommodation for Establishment ...	...	1,19,575	
Locks	...	7,28,700	
Mills	...	68,600	
		35,73,413	
	Establishment... ...	4,46,677	
		40,20,090	
	Add 30 per cent. as before...	10,72,024	
			50,92,114
	Patna Branch.		
Land	...	41,128	
Roads, Fences and Plantations	...	41,927	
Excavation	...	4,11,704	
Works for drainage and regulation of supply	...	33,000	
Falls	...	4,33,000	
Distributaries	...	6,97,700	
Bridges and Fords	...	3,35,697	
Accommodation for Establishment ...	...	98,900	
Locks	...	7,97,800	
Mills	...	47,700	
		29,38,556	
	Establishment	3,67,319	
		33,05,875	
	Add 30 per cent. as before ...	8,81,262	
			41,86,012
	Tikaree Branch.		
Land	...	25,656	
Roads, Fences and Plantations	...	29,599	
Excavation	...	2,48,748	
Works of drainage and regulation of supply	...	11,30,700	
Falls	...	1,74,000	
Distributaries	...	3,78,500	
Bridges and Fords	...	1,89,386	
Accommodation for Establishment ...	...	87,900	
	Carried over ...	22,64,489	2,06,95,036

		Rs.	Rs.
	Brought forward ...	22,64,489	2,06,95,036
Locks*		10,000	
Mills		36,400	
		23,10,889	
	Establishment	2,88,855	
		25,99,744	
	Add 30 per cent. as before ...	6,93,268	
			32,93,012
	Canals for Navigation only.		
Land		34,839	
Roads, Fences and Plantations		42,055	
Excavation —		4,95,819	
Drainage works		6,40,000	
Bridges		2,64,000	
Accommodation for Establishment		65,725	
Locks		11,72,000	
Mills		17,600	
		27,32,038	
	Establishment	3,41,503	
		30,73,541	
	Add 30 per cent. as before ...	8,19,611	
			38,93,152
	Grand Total ...	Rs.	2,68,81,200

The following is a more condensed abstract :—

Land		2,30,429	
Roads, Fences and Plantations...		2,31,511	
Excavation		32,69,840	
Drainage works		46,63,671	
Falls		16,09,000	
Distributaries		27,66,700	
Bridges and Fords ... —		15,83,159	
Accommodation for Establishment		6,46,175	
Locks		36,34,683	
Mills		2,25,000	
		1,88,64,009	
	Establishment	23,60,992	
		2,12,25,001	
	Add 30 per cent. as before ...	56,56,199	
	Grand Total as before ...		2,68,81,200

* It may be stated here that the charge for locks is only the excess over what it would cost to provide falls only: which with the small 60 × 10 feet locks is very trifling.

The amount of this estimate will doubtless appear large when compared with those for the Ganges and Baree Doab Canals. But this admits of explanation from four causes.

1st. As already explained there is a large allowance in the estimates for expensive foundations to the works.

2nd. I have added 30 per cent. as an allowance for the probable rise of prices during the execution of the works.

3rd. The Distributary Channels have not been included in former estimates for Canals of irrigation.

4th. The expense of the works for navigation is very great owing to the great slope of the ground ; and double locks have been allowed on the principal navigable lines.

The following analysis of the charges will show how far these last three causes have operated to increase the estimate.

Works for Irrigation only.

	Rs.	Rs.
Land	1,95,590	
Roads, Fences, and Plantations ...	1,89,456	
Excavation	27,74,521	
Drainage works	40,23,671	
Falls	16,09,000	
Bridges and Fords	13,19,159	
Accomodation for Establishment	5,80,450	
Mills	2,07,400	
	1,08,99,247	
Establishment at 12½ per cent.	13,64,272	
	1,22,63,519	
Add 30 per cent. as before	32,66,471	
		1,55,29,990

Distributaries only.

2,071 Miles at Rs. 1,300 per mile ...	26,92,300	
183 Miles of canal supplied with Modules, at Rs. 400	74,400	
Add 12½ per cent. for Establishment ...	3,45,837	
	31,12,537	
Add 30 per cent. as before ...	8,30,010	
		39,42,547
Carried over ...		1,94,72,537

		Rs.	Rs.
Brought forward			1,94,72,537
Navigation only.			
Lock Channels to Head works		1,94,124	
Locks in Irrigating Branches		22,72,900	
Navigable Canals—			
Patna line	2,55,147		
Arrah line	2,69,076		
Kurumnassa line	3,67,572		
Sasseram line	2,54,469		
Main Benares line	15,85,774		
		27,32,038	
		51,99,062	
Establishment at 12½ per cent. ...		6,49,883	
		58,48,945	
Add 30 per cent. as before		15,59,718	
			74,08,663
Grand Total as before ... Rs.			2,68,81,200

To compare the cost of the Ganges Canal with the above estimate of the cost of Soane Canals, we have the following data :—

		Rs.
In the Revenue Report of 1859-60 the total outlay, exclusive of Distributaries, is set down at		1,64,57,000
Add for Futtehgurh Branch		15,00,000
And for Bulundshuhur and Koel Branches		6,00,000
Total outlay to complete the works without Distributaries ...		1,85,57,000
Add for Distributaries say on 800 miles of canal, at Rs. 5,000 per mile (i. e., giving 5 miles of Distributary at Rs. 1,000 to each mile of canal)		40,00,000
Total cost... Rs.		2,25,57,000
Deduct cost of works for navigation—		
14 locks at Rs. 20,000	2,80,000	
Upper Navigable Channel	40,000	
10 lock channels below, at Rs. 8,000	80,000	
Cawnpoor Terminal locks	2,00,000	
		6,00,000
Cost of the Canal with Distributaries and without navigation ...		219,57,000

Now the cost of the Soane Canals as estimated by me is, excluding the 30 per cent. added,—

	Rs.
For the ordinary works, with Establishment	1,22,63,519
For Distributaries, with ditto	31,12,537
	1,53,76,056
Deduct cost of dam	18,04,205
Balance	1,35,71,851

which does not very greatly exceed half of the above estimate for the Ganges Canal, the discharges being 6,750 and 3,124 cubic feet per second respectively; and the rates for the Soane Canals about 10 per cent. higher on the average, in addition to the costly foundations allowed, and the double locks on the navigable lines.

	Rs.
For the Baree Doab Canal we have from the revised Estimate the total cost on a discharge about equal to that of the Soane Canals	1,35,09,491
Distributaries, as estimated by Captain Dyas, at 3 miles of Rajbuha to one of canal	17,45,000
Total ...	1,52,54,491
Deduct works for navigation, including share of Establishment, about	8,00,000
Cost of the canal, exclusive of works of navigation	1,44,54,491

The Baree Doab Canal rates for masonry are considerably higher than those in my estimate, so that it will be necessary to take the estimates with the 30 per cent. added, for comparison.

	Rs.
Canals without Distributaries, as above given	1,55,29,990
Distributaries	39,42,547
	1,94,57,443
Deduct cost of dam across the Soane with share of Establishment, &c.	22,85,326
Cost of Soane Canals, omitting dam	1,71,72,117

Which, as before, shows the Soane Canal estimate to be higher, owing however entirely to the difference in the estimated cost of the Distributaries.

The following Table exhibits the cost of the Soane Canals per cubic foot of discharge per second :—

Charges on the cubic foot per second of discharge.	Works with Establishment.	Add 30 per cent.	Total cost.
	Rs.	Rs.	Rs.
Canals without navigation works, on 2,524 cubic feet per second	4,859	1,295	6,142
Distributaries on ditto...	1,233	328	1,562
Total ...	6,092	1,623	7,604
Navigation works on 600 cubic feet per second	9,740	2,597	12,337
Total charges on 3,124 cubic feet per second	6,792	1,811	8,684

I have already said that I do not suppose it will be necessary to carry out the navigation works provided in the estimates to the full extent. The line of navigation with double locks on the Patna Branch is, I think, a necessity; and no more than the public would have right to expect as a compensation for the interruption to the navigation of the Soane, which the Canal Dam would cause. This expense must therefore be allowed to stand in full. Of the other lines, no doubt that towards Benares is the most important, and most likely to pay well, though it would be expensive. If the whole scheme were to be carried out at once, it would be best perhaps to restrict the navigation to these two—that is, the navigation with large double locks. The revenue to be derived from the two would probably not be to any important extent less than what would be derived from the four lines.

But the cost of the Benares line is so large, and the work itself is one so entirely distinct from the rest of the project, that it will be best to assume that it will not be constructed at first; and to provide a substitute for it. The Kurumnassa line is the one to adopt for this purpose; but I would adopt it only as a line with single locks. If the traffic become too great to be carried upon

such a line, it would be time at once to undertake the Benares line.

I propose then to reduce the Arrah line to one of navigation only by the small locks of 60 × 10 feet chamber. This will admit of a slight reduction of the supply of water, and so the cost will on the whole not exceed what has been set down for the irrigation only. We get rid then of the whole charge for navigation estimated for this line, viz. :—

Locks on the Irrigating Canal	Rs.	7,36,400
The Navigation Canal		2,69,076
	Rs.	10,67,476
Establishment for ditto ...	"	1,33,434
	[illegible]	[illegible],00,910
30 per cent. added	[illegible]	3,20,243
Total ...	Rs.	15,21,153

To which may be added one lakh of the cost of carrying the navigation down the Bunas to the town, with share of Establishment, &c. Total say 16 lakhs.

I next propose to reduce the navigation on the Kurumnassa line to one with single locks. There are—

4 Locks on the Buxar Branch Upper, share chargeable to navigation	Rs.	1,77,600
2 Ditto on the Chowsa Branch Upper ditto	"	59,800
The navigable canal alongside the lower part of this branch ...	"	3,67,572
And one lakh of the cost of the descent into the Ganges ...	"	1,00,000
	Rs.	7,67,362
Deduct 6 single locks to be allowed in lieu of those entered above at Rs. 22,000 each	"	1,32,000
	Rs.	5,72,972
Establishment charge	"	71,223
	Rs.	6,44,794
Add 30 per cent. as before	"	1,71,891
Total ..	Rs.	8,16,685

So that with these two reductions in all of Rs. 24,00,000, the whole cost of the project may be set down at 245 lakhs; which may be laid out in portions, as will be explained in a subsequent section.

Section XV.—Income, Expenditure, and Profits.

A.—Income, &c., from Irrigation.

Before proceeding to fix the rates of charge and probable returns from the irrigation, it will be satisfactory to review the assessment of the Land Revenue of the tract into which the irrigation is to be introduced, and its incidence on the area and population; and to compare South Behar in these matters with the neighbouring districts of the North-Western Provinces.

The following are the Pergunnahs* of Shahabad (west of the Soane), which will be either entirely, or with very little exception, under the influence of the irrigation:—

Names.	Population.	Area. Square miles.	Assessment of Land Revenue. Rs. per annum.
Dunwar	1,21,950	336·4	64,724
Dinareh	44,345	55·1	19,074
Chowsa	74,965	201·2	81,824
Peeroo	1,31,710	201·5	56,218
Nonore	1,10,960	107·3	29,876
Ponwar	91,345	113·3	51,409
Beeheea	1,14,170	231·3	1,05,246
Bhojpoor	2,29,979	423·6	1,59,720
Total ...	9,19,424	1669·7	5,68,091

This gives a population of 556 per square mile, and a Land Revenue of As. 9-10 per head of population, or As. 8-7 per acre of gross area.

The population of the whole district, including the hilly tracts, is 367 per square mile, and the assessment As. 10-8½ on the gross area.

There are unfortunately no similar statistics on record for the Districts of Behar and Patna, east of the Soane. The Report of the

* The maps printed with this Report do not show the boundaries of the Pergunnahs. They will be found in the 88th, 89th, 103rd and 104th sheets of the India Atlas, published by Mr. J. Walker, Geographer to the Secretary of State for India. The figures above are taken from the Official Return by Mr. Travers, Collector of Shahabad, dated 9th April 1849.

Revenue Surveyor Lieutenant (now Lieutenant Colonel) W. Maxwell gives the population of Patna, according to a census of 1837, at 845,790 souls, including the city, which contained 284,132. The area of the district is 1,835 square miles. The population per mile, excluding the city, is thus 306 souls. For Behar we have only a very imperfect statement, based on the Chowkedaree Tax papers, which makes the population altogether 10,000,000, which on the area of 5,694 square miles gives only 176 souls per square mile, on an area including very large tracts of hills and jungle.

The portion of country irrigated by the Eastern Soane Canal contains some of the best tracts in both districts, and I should suppose is not, *on the average*, less populous than the country to be irrigated in Shahabad, west of the Soane. The upper parts near the trunk road are no doubt less populous; but the population increases in proceeding towards Patna.

If we now take the same particulars of the Pergunnahs of the Districts of Ghazeepoor and Benares on the south of the Ganges, we shall find*

Names.	Population.	Area. Square miles.	LandRevenue. Rs. per annum.
Ralhoopoor	26,966	28·5	35,055
Mowaee	9,748	17·8	20,929
Mahooaree	18,375	32·7	23,982
Buruh	25,287	47·0	45,505
Dhoos	20,934	45·8	28,092
Mujhwar	39,535	75·9	40,975
Budhwul	31,755	65·5	32,912
Nurwun	39,723	105·6	57,212
Muhaitch	46,067	85·2	61,388
Zumaneeah	173,641	288·8	1,74,263
Total ...	432,030	791·8	5,17,313

which gives a population of 545 per square mile, with a revenue of Rs. 1-1-11 per head of population, and Rs. 1-0-6 per acre of gross area. The area of actual cultivation is 372,284 acres, or 73·3 per cent. of the whole, so that the Land Revenue on this will be Rs. 1-6-6 per acre.

* From the Report of the census of 1851, in the North-Western Provinces.

It will be seen that the assessment here is double that of Shahabad on the same population.

The three best Pergunnahs of the Benares District, after excluding those in immediate contiguity to the city and on the bank of the Ganges, are:—

Names.	Population.	Area in square miles.	Land Revenue. Rs. per annum.
Uthganwan	26,103	35·8	48,252
Kuswar Sirkar	32,048	43 9	50,985
Pundruha	35,818	46 7	57,786
Total	93,969	126·4	1,57,023

This gives a population of 743 per square mile, with a Land Revenue of Rs. 1-10-9 per head of population, and Rs. 1-15-0 per acre of gross area. The total cultivation is given at 51,211 acres, which gives an assessment of Rs. 3-1-1 per acre of actual cultivation. The cost of irrigation is probably at least as much more.

The total area over which the irrigation from the Soane canals is to extend is (see Tables, pages 14 to 17) 3,355 square miles; which, according to the rates deduced for the Pergunnahs of Shahabad,* has probably a population of 550 per square mile, or 1,845,250 souls in all, and is assessed at the rate of As. 9-10 per head of population, and As. 8-8 per acre of gross area, making the total assessment of Land Revenue of about Rs. 11,00,000. If the actual area of cultivation is ⅔rds of the gross area, as in the Benares District, it may also be concluded that the assessment on the area of actual cultivation is As. 13-0 per acre.

If on the completion of the canals the land were considered to be placed on an equality with the best Pergunnahs of Benares (not possessed of canal irrigation), the assessment at Rs. 1-15 per acre of gross area would give a revenue of Rs. 41,60,200 per annum, or an increase of Rs. 30,00,000 above the present rate; that is of course supposing the return for the canal to be looked for in the increase of Land Revenue only instead of in the water rate.

* Two-thirds of the area to be irrigated is in Shahabad.

Or, if the rate be taken at Rs. 1-10-9 per head of the population, the revenue would rise to Rs. 30,75,000, being an increase of Rs. 19,75,000 on the present revenue. The mean of these two would give an increase of Rs. 25,00,000, which may therefore be considered as equivalent to taking the returns for the canal in increased Land Revenue instead of by levying a water rent. It must be remembered that this supposes the assessment to be made equal to that of certain Pergunnahs of Benares, where the cultivators, in addition to the assessment on the land, have themselves to provide the irrigation at a great expense from wells; whereas the irrigation is supposed to be provided from the Soane canals free of all charge, and yet the same assessment only levied.

But we are dealing now with permanently settled districts, and have nothing to do with enhancement of Land Revenue. I have only brought these figures forward to give some idea of the aspect of the revenue derivable from the canals, considered in reference to the total burdens on land and population.

In the 20th paragraph of my Report of 1855, (Appendix page xx.) I concluded that a cubic foot of water per second would suffice for the actual irrigation of 512 beegahs (320 acres) of spring crops; and in the 17th paragraph (page xx.) that we could supply this water to the cultivator for Rs. $1\frac{1}{4}$ per beegah, giving him thereby twice as much water as he before obtained for the purpose at Rs. $1\frac{9}{16}$ per beegah. In the calculation nothing is allowed for the cost of sinking and repairing wells; and, as an ordinary unbricked well in Shahabad often lasts only one season, this is a considerable item in the charge. I calculated moreover upon no other receipts from the supply of water, but to give the same quantity all the year round for no further charge than the Rs. $1\frac{1}{4}$ per beegah, the water would therefore be available to the cultivator in the rainy as well as in the dry season, and would save his rice crop from injury or total loss in case of scanty rains. Since 1855, however, so great a rise of prices has taken place that the rate may fairly be increased by 25 per cent., or to Rs. $1\frac{9}{16}$ per beegah.

Since 1855 the Government has decided that the cost of the Distributary Channels or Rajbuhas which before was borne by

the cultivator should be borne by the Government, and that an addition should be made to the water rate to meet this charge. This addition has been fixed at Rs. 100 per cubic foot per second of discharge of the Canal. It consists of Rs. 21 as interest on the direct outlay, and Rs. 75 for repairs of the channels, with Rs. 4 added to make even money. This charge in fact takes the place of the cost of constructing and repairing wells, and divided over the 512 beegahs comes to about $\frac{1}{5}$th of a Rupee, or $3\frac{1}{5}$ annas per beegah.

The water rate of the Soane Canals thus fixed will therefore come to $1\frac{9}{16} \times 512 + 100 =$ Rs. 900 per annum for each cubic foot of discharge per second at the canal head; allowance having already been made for wastage (see Report of 1855). This will be in all Rs. 1-12-2 per beegah (Rs. 2-8-10 per acre) of spring crop (wheat or barley); charge being made for the autumn crop (rice, &c.)

The full rate should not be applied at first, but the water supplied at very low rates till the people have learnt its value, when the rate would be gradually raised.

In the revised estimate of the Baree Doab Canal the revenue from irrigation is thus calculated, on 3,073 cubic feet per second of discharge, of which 130 feet is I believe reserved for Navigation*—

Water Rent	Rs.	15,80,500
Increased land revenue	"	9,31,000
	Total Rs.	25,11,500

which is at the rate of Rs. 853 per annum per cubic foot on 2,943 cubic feet of discharge. Add to this Rs. 100 from the expenses of Distributaries, and the gross income becomes Rs. 953 a year per cubic foot of discharge per second.

For the Ganges Canal, Colonel Baird Smith calculates, on the 6,750 cubic feet of discharge per second, deducting 400 cubic feet reserved for Navigation—

Water Rate	Rs.	13,27,500
Increase of Land Revenue	"	23,90,400
	Total Rs.	37,17,900

* Para. 7, Section VI., of original Report by Capt. Dyas.

or Rs. 585 per cubic foot on 6,350 feet of discharge per second. But this is assuming the water rate at the low charge of Rs. 220 per cubic foot, which was fixed from the beginning of the irrigation. With the Rs. 100 added, as before, this comes to Rs. 685 yearly per cubic foot per second of discharge. The rate of direct water rent here is so low that one of the Executive Engineers states that if he were allowed to charge the Jumna Canal rates, his revenue would be all but doubled. It is however no doubt advisable to maintain the low rate for the present on the Ganges Canal.

From the Western Jumna Canals we can gather no conclusions, because the errors of level of the old bed have as yet not been rectified, and the system of Distributaries has only been partially established.

From the Eastern Jumna Canals the returns were in 1858-59 Rs. 1,66,379, which, taking the discharge at 900 cubic feet per second, gives a rate of Rs. 184 per cubic foot. In 1859-60 the gross water rent had risen to Rs. 2,45,206, giving a return of Rs. 272 per cubic foot. In 1860-61, I learn from Colonel Baird Smith that the return has risen to Rs. 200 per cubic foot per second for the spring crop only, with a nearly equal revenue from the autumn crop. The discharge of the canal only averaged 665 cubic feet per second in the spring, owing to the effect of the drought upon the Jumna; but it was as much as 1,500 cubic feet per second during the rains. The total revenue was thus nearly equal to Rs. 400 upon the dry season discharge of the canal. Taking the rate at Rs. 272, and adding, as in the case of the Ganges Canal, Rs. 330 for the improvement of the land, and Rs. 100 for the charges of the Distributaries, the rate comes to Rs. 703 yearly per cubic foot per second of discharge; and at the rate on the spring crop of 1860-61, it would come to Rs. 831. I have added the Rs. 100 here because the Distributaries had already been for the most part paid for by the cultivators.

The Eastern Jumna Canal is the best example we have of a well regulated irrigating canal, but it is only lately that the improvements in engineering and administration that have been going on for many years, have produced their effect upon the

revenue. In new projects we have the benefit of all these improvements for our guidance, and may hope for a quicker but still only gradual development of returns.

Returning now to the Soane Canals—

The total discharge of the Western Canal is	... Rs.	1,980	cubic feet per
And of the Eastern Canal	... "	1,144	second.
Total	... Rs.	3,124	
Deduct allowed for Navigation	... "	600	
Balance	... Rs.	2,524	

On this I propose (as the ultimate rate) to charge Rs. 900 per cubic foot per second of discharge, which comes to Rs. 22,71,600; which sum may be compared with the figures deduced in a previous paragraph as the possible increase of Land Revenue if the country were placed on an equality with a part of the Benares District.

The annual expenses to be charged against this are reckoned by Sir P. Cautley, on the analogy of the Eastern Jumna Canal, at

Establishment per cubic foot per second,	Rs.	47	yearly.
Ordinary repairs...	"	44½	"
To which is to be added, as just mentioned, for repairs of Distributaries ...	"	75	"
Total ...	Rs.	166½	

or say Rs. 170 per 100 cubic feet of discharge, which, deducted from the gross income of Rs. 900 per annum, will leave a net income of Rs. 730 per annum per cubic foot of discharge devoted to irrigation.

The net income from irrigation then stands thus; 2,524 cubic feet yielding Rs. 730 each per annum, Rs. 18,42,420.

B.—Income, &c., from Navigation.

The Calcutta Canals afford a good example of what may be earned by Navigable Canals leading to a large city which is yet itself upon a navigable river. The Calcutta Canals are chiefly natural channels which have been improved, and connected and brought into contact with the City of Calcutta by means of artificial canals, of which the aggregate length is 32 miles. The whole length of the navigation is 120 miles, and tow-paths have been constructed and are kept in repair for the whole distance. The width of the artificial channels at floor is 44 feet, the depth at low water 3 feet, and the rise of the tide 4 to 11 feet. The headway allowed under the bridges is 15 feet, which admits of the country river craft passing with their high sterns and rudders. There are locks only to keep out the high tides of the Hooghly. These canals form the connecting line of traffic with Dacca and the east of Bengal. They possess two advantages which can hardly be found elsewhere. The first is, that the country to the eastward is such that there is no land communication, and these canals form the only line of traffic except the dangerous and uncertain one by the sea; and that with a very rich country. But secondly, they connect the City of Calcutta with the Soonderbuns or swamp forests of the Ganges Delta, where an inexhaustible supply of wood is found, intersected by creeks in all directions, and growing down to the water's edge. More than half the revenue of the canals is derived from fire-wood. See the following Table:—

Return of the Goods passed through the Calcutta Canals during the year ending 30th April 1861.

	Maunds.*
Fire-wood†	310,00,000
Coal..	16,25,410
Charcoal..	1,19,850
Lime	5,24,375
Carried over ..	332,69,635

* About 27 maunds go to a ton.

† This is not given separately in the Official Return, but is known to be about 80 per cent. of the "Sundries," from which I have separated it.

Brought forward ..	332,69,635
Salt..	39,95,100
Oil seeds	23,27,795
Grain, chiefly rice..	63,68,739
Cotton and Piece Goods*	1,52,800
Indigo, Tobacco, Sugar and Molasses ..	13,24,525
Jute	12,57,650
Sundries..	77,88,787
Total ..	564,85,030

The toll was during 1860-61 eight annas per 100 maunds. The income and expenditure on the average of the last three years were as follows:—

	Rs.	Rs.
Gross income..		2,93,134
Charges of Collection and Police..	33,463	
Engineering Establishment ..	32,872	
	66,335	
Repairs	35,321	
		1,01,656
Net Income ..		1,91,478

Of this 73,637 was on the average devoted to improvements—in fact was added to capital during each year.

But the rate of toll has been increased during the current year to 12 annas per 100 maunds, and this has had no effect upon the traffic, and is realizing a clear increase of 50 per cent. on the gross revenue, or bringing it up to Rs. 4,50,000.

In contrast to this we may place the Western Jumna Canals, which, connecting the City of Delhi with the forests of the Lower Himalaya, yet only realize 10 or 11,000 Rupees from rafting timber, bamboos, &c. The main cause of this short-coming in the Western Jumna Canal is no doubt the fluctuations of water arising from the demands of the irrigation.

* The year is one of very depressed trade in Piece Goods.

The canals of the North-Western Provinces carry a limited supply of water into what is practically an unlimited extent of land, so that as the irrigation developes, and especially in seasons of unusual demand for water, the supply is liable to be all but totally absorbed, unless special arrangements are made to prevent it. In the Ganges Canal it is intended to place the irrigation outlets at such levels as not to allow of the Canal being run dry for irrigation at its lower extremity. But the Ganges Canal is not yet sufficiently long in use to admit of our drawing conclusions from it; and the feeling with Canal Engineers in the North-Western Provinces is that navigation and irrigation cannot be satisfactorily combined. It may be remarked however that notwithstanding the loud complaints which have been made as to the excessive velocity of the current, the want of headway in the bridges, and the want of tow-paths within the arches, the revenue from navigation is the only branch of the revenue from the Ganges Canal which *has already* exceeded what the projector calculated upon.

The Madras Engineers, on the other hand, hold a totally opposite opinion, and mention that they have succeeded in the combination of irrigation with navigation, and do work their canals in both ways with perfect success. Sir A. Cotton's printed Statement shows that in the fourth year after the opening of the Godavery works, 18,800 boats passed through the three principal channels, and 8,300 descended the main channel to the Port of Coringa; the number of the latter had risen two years after to 13,400.

With such conflicting opinions and examples it is difficult to form any definite notion of what the income for navigation of the Soane Canals is likely to be. But for the following reasons I think it must be admitted that the Western Jumna Canal cannot be looked upon as a fair example to judge by.

The Soane Canals do not afford irrigation to a vast plain like those on which the Canals of the N. W. Provinces expend their waters; but the area is limited, and the supply of water calculated on a liberal scale for that area, so that it is not likely to be absorbed to such an extent as to trench upon the supply specially allowed in excess for navigation; which, however, will also be preserved by preventing the distributary channel heads being placed

so low as to draw it off. Besides which, locks of communication with the Ganges will be given, which is an advantage not possessed by the Jumna Canals.

In the next place we have the supply of excellent lime-stone at the canal head all along the foot of the Kymore Hills. This lime-stone is now collected on the Soane banks and carried down that river in the rains. The quantity used formerly to be 1,25,000 maunds per annum, even with that uncertain navigation in only one direction.* Of late some unfortunate mismanagement in the competition with the coal for the limited supply of boats on the Soane has led to such difficulty in obtaining boats that the traffic has fallen off to 25,000 maunds. But there can be no doubt that it will rise again with the facilities of transport; and the new market that will be opened for it to Benares and Ghazeepoor will at least double the original large consumption. It will be also able to compete with the Sylhet lime, which with a nearly equal distance of carriage has long had almost a monopoly of the Calcutta market, and that of all lower Bengal. Besides the lime as used for cement we have the lime-stone for paving, and the excellent sand-stone for various building purposes. Both these may be brought into shape fit for the market by water power at the canal falls.

Thirdly, we have the coal of the Rajhurra collieries and other coal fields of the Palamow District. At present the out-turn of the coal is very small, only 30,000 maunds per annum. But there can be no doubt that it will, with the lime, increase immensely on the provision of secure means of conveyance northwards, and the opening of a new and safe line of carriage to the west. The position of the proposed head of the canal will still leave 50 miles of land carriage, or of dangerous navigation by the Koel and Soane, but reducing the distance of such carriage, as these canals will do, to one-third of what it now is, must have a great effect; and the completion of the communication by canal or railway must follow. To what extent the coal will ultimately come into use it is impossible to guess. It will doubtless be very much more largely consumed than the lime.

If these advantages be compared with those possessed by the Calcutta Canals, and bearing in mind that the Cities of Patna and Benares each rival Calcutta in population, and that a higher rate of toll will be fairly applicable to the Soane Canals, in proportion to the greater obstacles overcome, it will not be deemed unreasonable to expect that the traffic on the Soane Canals will in the aggregate ultimately realize Rs. 2,00,000 per annum.

C.—Corn Mills, &c.

The next source of income is the Corn Mills. The income derived from the rent of these buildings on the Eastern and Western Jumna Canals for the last two official years is as follows:—

Canal.	No. of Mills.	Income.	
		1858-59.	1859-60.
Eastern Canal	12	6,279	8,194
Western do.	11	5,538	3,533
Total	23	11,817	11,727

This gives an average of a little over Rs. 500 per annum for each mill. On these canals each mill has usually three pairs of stones. Those proposed for the Soane Canals are of two kinds, the double house mills have six pairs and the single house mills three pairs of stones. I shall estimate the income from all at one uniform rate of Rs. 500 per mill. As there are in all 135 mills included in the estimate for the Soane Canals, the probable income thus calculated will be Rs. 67,500.

Besides this, we may expect ultimately to obtain a considerable income by using the water power in other ways, especially by the construction of mills to cut the lime-stone for paving marble, and the sand-stone for flags.

Lastly, we have the usual income from the sale of the produce of the canal lands, and the fines for breach of canal regulations, which may be estimated at Rs. 7½ per cubic foot per second

of total discharge for the canals only, and adding that of the land on which the Distributaries are located, which is now to be Government property, it may be made up to Rs. 10. This will give Rs. 31,240 per annum.

On the whole then I estimate the net revenue as follows :—

	Rs.
Sale of water for irrigation	18,42,420
Tolls on Navigation	2,00,000
Mill rent	67,500
Miscellaneous	31,240
Total Rs.	21,41,160

which would give a return of 8¾ per cent. on the outlay of 245 lakhs of Rupees which I have recommended.

If it were not for the Navigation, the profits would come to 10 per cent. per annum.

The revenue will however be of slow growth, and it will do harm to attempt to hasten it. We must recollect that the canals must be used to enrich the people before they will be able to afford to pay in full for the water. I do not expect that the rate of profit would reach 5 per cent. for 8 or 10 years after the irrigation is brought into operation.

Section XVI.—Methods of carrying out the works gradually.

It will probably be considered desirable to carry out the works by degrees, and if so, I think the Patna line is the one to commence with, as it includes the navigation which will replace and supersede the most directly that of the Soane river.

In order to carry out this branch, it would not be necessary to construct the permanent dam across the Soane. We may, with the temporary dam, calculate upon getting 4 feet depth of water in the Eastern Main Canal, which will give a discharge of 534 cubic feet per second,—within 200 feet of the full discharge of the Patna Branch. In the rainy season the full discharge would of course be available for the rice crops.

The cost of this portion of the work would be as follows:—

		Rs.
Temporary Dam ...	... ...	2,24,469
Eastern Lock Channel Head	... ...	60,151
Share of all other expenses of the Head works, say	... ...	1,00,000
		3,84,620
	Establishment	48,077
		4,32,697
	30 per cent.	1,15,386
	Total for Head works	
Eastern Main Canal ...	... ...	13,01,458
Patna Branch and subordinate lines	...	41,00,000
Patna Navigation line	... ...	3,63,584
	Total ... Rs.	

The outlay would be spread over about 5 years. Probably 5 lakhs of Rupees would be required in the first; 16 in the second year; and the remainder at 16 lakhs a year in the three last years.

The return to be expected may be reckoned as follows, 138 cubic feet per second of the above-mentioned discharge being reserved for Navigation.

	Rs.
400 Cubic feet per second of discharge for irrigation, at Rs. 900 ...	3,60,000
Deduct charges on a larger supply to make up for the repairing of larger channels, say on 600 cubic feet per second, at Rs. 170 ...	1,02,000
	2,58,000
Net return from Navigation, say	1,00,000
27 Mills at Rs. 500 each	13,500
Sale of produce, &c., at Rs. 10 on full supply discharge of 800 cubic feet	8,000
Total Rs.	3,79,500

which would give 6 per cent. on the outlay.

If a further outlay could be afforded, the Arrah Branch might be undertaken simultaneously, or immediately after the above. For this similarly we should not require to construct the permanent Dam. Without it we should be able, at the Lock Channel

Head, to get 5½ feet of water in the Western Main Canal, which will give a supply of upwards of 1,000 cubic feet per second, of which we cannot use on the Main Line and Arrah Branch above 840 cubic feet per second, allowing 100 cubic feet for navigation with small locks.

The outlay required will be—

	Rs.
Western Lock Channel Head	1,33,973
Other expenses at the Head works, say	66,027
	2,00,000
Establishment	25,000
	2,25,000
30 per cent. added	60,000
	2,85,000
Western Main Canal	17,74,276
Arrah Branch, excluding cost of large locks with the share of Establishment and other charges due to them	33,33,475
	53,92,751

The returns would be—

740 Cubic feet per second for irrigation, at Rs. 730 *net*	5,40,200
Navigation with small locks, say	10,000
31 Mills at Rs. 500	15,500
Produce, &c., at Rs. 10, on 840 cubic feet per second of discharge ...	8,400
Total ... Rs.	5,74,100

equal to 10½ per cent.

The united outlay for these two parts of the project would be 118 lakhs, and the united net returns Rs. 9,53,600, being 8 per cent.

To undertake the Arrah Branch first, would yield a more tempting return; supposing, as above, that no large locks for navigation were attempted. The outlay, if the temporary dam were charged upon this work, would exceed by about three lakhs what has been above set down; but would yet yield a profit of 10 per cent. per annum on the same calculation. The temporary dam

on the Soane would not be a much greater obstruction to the navigation than the temporary bridge at Dehree for the Grand Trunk Road; and the withdrawal of 840 cubic feet per second from the Soane would, in ordinary seasons, make no appreciable difference in the navigation. I should however regret a determination to commence upon this line only, as delaying the introduction of the improved navigation, which, although we cannot reckon with certainty upon such large returns from it as from the irrigation, seems yet to be of more importance as a public benefit.

APPENDIX A.

REPORT OF 1853.

From Lieut. C. H. Dickens, *to the Secretary to the Govt. of Bengal.*

Calcutta, *25th January* 1853.

Sir,—I have the honour to request you will do me the favour to lay before the Most Noble the Governor the accompanying Note of a project for Canals chiefly for irrigation in certain districts under the Government of Bengal.

2. I need not say anything to prove the advantages of irrigation, which it is well known is in many parts of India the only means by which a spring crop can be produced at all, and in the drier of the localities where a spring crop can be raised without irrigation, the introduction of irrigation has been found to increase the produce by 50 per cent. The labour attendant on the common modes of irrigating the crops is, however, a circumstance not so generally considered, but it is a matter of immense importance when it is borne in mind that all the vast quantity of water procured from wells, or from tanks below the surface of the soil for irrigation has to be raised from 10 to 30 or 40 feet in order to be applied to the crops. It must be evident that the expenditure of so much labouring force as is required to raise this water is a great drain upon the productive resources of the country, and the construction of works affording means of reducing this labour, is a most important public benefit. Some definite idea of the effect of such works may be formed from the consideration that the Ganges Canal is calculated in irrigation alone to perform the work of nearly 300,000 men and 1,200,000 bullocks employed throughout the irrigating season; and besides this will afford labouring force in the way of transport of goods by rafts or boats propelled by its current, and in turning machinery by the more rapid flow of its waters at the falls.

3. To explain briefly the nature of the project I submit, I must observe that in Northern India there are two methods practised on the large scale for obtaining the advantages of irrigation for the crops by the natural flow of water, that is avoiding the expense of raising the water by machinery or animal labour. One of these methods is to dam across small valleys, so as to arrest the surface drainage water of the rains, and to cause it to flow out in the proper season upon the fields below the dams; the other method

is the conveyance of water in canals from rivers in the hills so as to cause it to flow down upon the plains at a higher level than the land to be irrrigated. The first mode is applicable to parts of the country having a succession of high and low lands at short intervals,* and the second to extensive plains lying at the foot of masses of hills in which there are rivers having a considerable supply of water all the year round.

4. In addition to the advantages of irrigating much of the land by the natural flow of water, the two kinds of works alluded to admit of extension of irrigation by the use of labour, and commonly by a smaller expenditure of labour than is required to raise water from wells or from tanks at the ordinary depth below the soil, and in the cases in which they have been constructed, the retaining dams and the canals have afforded a good supply of water where before the supply was scanty, uncertain, or altogether wanting.

5. The plan I propose is a combination of the two abovementioned methods of procuring irrigation by the natural flow of water to suit the case of extensive plains lying at the foot of hills, in which there are no rivers having any considerable supply of water in the dry season. I propose to form reservoirs in the hills to be filled by surface drainage from the rains, and to lead the water of these reservoirs by means of canals over the plain country for use during the dry months.

6. The paper contains such a general discussion and feasibility of the project and of its prospect of being beneficial to the people and profitable to Government as I have been able to draw up from the information I could procure, chiefly Colonel Cautley and Colonel Dixon's works; but I have not thought it advisable to draw plans of canals or reservoirs, or to fix upon their courses, sites, or dimensions, without the precise information only to be procured by a special survey of the locality in which it is proposed to construct the works.

7. My plan does not contemplate any heavy expenditure until after a full local investigation and subsequent experiment on a small scale shall have proved the project to be feasible and beneficial, and then it can be extended gradually as financial convenience and other considerations may render its extension desirable.

8. I beg to add that I have not ventured to submit this paper for the orders of Government without consulting the Engineer Officers residing in Calcutta and others I thought likely to be able to judge of the matter, and that the opinions I have obtained from all are such as to lead me to hope the project may prove worthy of adoption.

I have, &c.,

C. H. Dickens, *Lieut.*

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* This includes continuous somewhat steep slopes.

NOTE ON A PROJECT FOR CANALS IN CERTAIN DISTRICTS OF BENGAL.

At a time when the constructions of canals for irrigation and navigation is attracting so much attention in India, it may be acceptable to the Government to bring forward a scheme by which works of the same nature may be constructed in districts within the jurisdiction of Bengal.

2. I shall chiefly confine my remarks to the Shahabad District, because it is the best suited to my purpose, and because I am better acquainted with it than with any other district under the Government of Bengal. What is said of Shahabad will, however, be in a great measure applicable to the other districts, to which I shall afterwards briefly refer.

3. The district of Shahabad is in shape nearly triangular, its shortest side to the south-west being in mass of hills of considerable elevation, and of the two longer sides, the one to the north north-west is bounded by the Rivers Kurumnassa and Ganges, and the other, to the south-east by the Soane. The rivers which take their rise in the hills to the south-west of this district, like most other hill streams, become very violent torrents in the rainy season, and cut their channels deep below the surface as they descend into the plains. In the dry season consequently when there is but little water left in the channels, that little water is so far from the surface as to be deprived of much of its value for irrigation, because of the great labour that must be expended to raise it to the level of the crops. I have seen no fewer than 14 men in the irrigating season employed at one time and in one spot raising water stage by stage from the channel of the Kurumnassa River to irrigate one small patch of cultivation. And with wells the expenditure of labour is not less, for the water in them is no nearer the surface.

4. Now a canal for irrigation, the supply of which is derived from hills, is so contrived as to descend by an easy slope to the plains, so that the water surface shall not, as in rivers, be suddenly carried deep below the surface of the soil, but shall always remain above, or at least not much below it. The consequence is that, in supplying the water of a canal to irrigation, all labour of raising it to the surface is avoided, and a mere opening in a channel led from the canal to the field to be irrigated is all that is required. If a properly contrived canal were constructed to pass by the spot when I saw the 14 men employed in raising the water from the Kurumnassa, one or two boys to open and close the irrigation openings would do all the works of irrigation, and the 14 men and others similarly situated would be at liberty to apply their energies to cultivating more land, or could devote themselves to some branch of productive industry.

5. From this it appears that a canal must be wanted whereever the crops require irrigation, and that the urgency of the want will depend on the depth below the surface from which the water must be raised to be applied to the crops. The banks of the Kurumnassa are nearly the lowest part of the Shahabad District, and the water there is from 25 to 30 feet below the surface of the soil. It is likely therefore that water will in general not be found much nearer the surface in the rest of the district, and I may, I think, infer that canals must in general be much needed there.

6. From the direction of the water-courses it appears that in crossing the district any where in a direct line from the Soane to the Ganges, the highest portion of the route would be found near the Soane nearly in a line from Sasseram to Arrah. The district may naturally be expected to have a fall from Sasseram towards Arrah, though it would appear that the difference of level is not great. There may perhaps be difficulty from want of sufficient fall in carrying a canal all the way to Arrah; but for the greater part of the district there is evidence of ample slope of the ground towards the Ganges, and 200 miles of canal might very advantageously be laid down, it appears, with no engineering difficulty worth speaking of, if we could only be assured of a sufficient supply of water from the hills.

7. The water for the supply of Jumna and Ganges Canals is afforded by the rivers from which they derive their names. But in the hills in the south-west of Shahabad we have no streams of sufficient magnitude in the dry season to supply 200 miles of irrigation canal. We must therefore resort to the method of supply by reservoirs. This means is very commonly resorted to in the canals of Europe, where rivers cannot be made available, although of course inferior in convenience and efficiency to a river supply. The reservoirs are generally constructed by throwing dams across valleys, particularly mountain valleys, and are contrived to receive drainage water from heavy rain, and all small streams in the neighbourhood which the owners of the land can spare are also directed into the reservoirs, and it is even found worth while in some parts of England to hire the Sunday discharge of Mill-streams, and to pump water by steam from marshes and fens.

8. Now the difference between the nature of the process by which the supply of the reservoirs of the canals I propose is effected, and that by which reservoirs in Europe are filled, arises from two circumstances: first, from the supply for a canal of irrigation in this country being so much greater in proportion than for any canal fed by reservoirs in Europe; and secondly, from the effect of the periodical rains, which will oblige us to collect and store all over water in one grand operation during the rainy season, and to discharge it all in one grand operation in the dry season, so separating two pro-

cesses which in Europe are carried on to some extent simultaneously.

9. The result of both these points of difference is, that the body of water to be collected in the reservoirs for the canals I propose must be vastly greater than what is required for European canals; and in this result is contained the whole difficulty of the scheme I bring forward.

10. In estimating the required and probably obtainable supply of water, it will be convenient to state the quantities in terms of the depth to which the water would fill a reservoir of a mile square and with perpendicular sides. This will be more brief and clear than speaking of millions of cubic feet. For the Grand Junction Canal in England, the 8 reservoirs contain about 1,600 millions of cubic feet, that is, about 58 feet in depth of this imaginary reservoir of a mile square. This supply is for 90 miles of navigable canal. But for 100 miles of irrigation canal in India, of sufficient magnitude to irrigate the lands for 4 or 5 miles on each side of it, Colonel Cautley estimates the supply of water required at 800 cubic feet per second, which for a dry season of 300 days* would be 744 feet in depth of the imaginary reservoir, or more than 12 times the quantity required for one of the largest canals in England. I have not been able to find any sufficiently detailed account of the canals of Italy and the South of France, to enable me to state how far their supply is derived from reservoirs ; but it appears that reservoirs are extensively resorted to in those countries for irrigation.†

11. The supply required for the 200 miles of canal for the Shahabad District would therefore be a quantity of water equal to 1,488 feet in depth of this imaginary reservoir to be stored up annually in the hills, but this is from Colonel Cautley's estimate for the maximum supply of a canal fed by rivers. For a canal fed by reservoirs it would be extravagant to allow all the year round the full supply which is only required during the irrigating season; during that season the full supply might be allowed say for 60 days, and for the rest of the season when the water would only be required for ordinary household wants and for the want of cattle for certain minor crops, and to make up for loss by absorption and evaporation, perhaps one-fourth of the maximum supply would suffice. If this can be arranged the whole supply for the season need not be more than 600 feet depth of the reservoir, that is of water actually to be discharged by the canals, and allowing 50 per cent. for absorption and evaporation in the reservoirs, the total

* The dry season is usually 9 months or 270 days, I allow a margin of 30 days.

† [This was a mistake as regards Italy. See Colonel Baird Smith's Italian Irrigation, since published.—1861.]

quantity to be stored up may be reckoned at 900 feet in depth of the reservoir of one mile square.

12. To judge of the practicability of retaining this quantity of water three points must be considered:—

1st. Whether so much can be drained off from the surface of the hills.

2nd. Whether it can be brought into the reservoirs.

3rd. Whether it can be kept long enough in them.

13. In considering the first point, I shall begin by stating the bulk of rain water which falls in the hills. The fall of rain in that part of the country is generally from 30 to 50 inches in the year, say 36 inches or 3 feet. Then the area covered by the hills about 1,000 square miles, the total fall of rain will be equal to 3,000 feet in the depth of the imaginary reservoir, so that if we could collect but one-third part of this, the quantity would be ample for the proposed 200 miles of canal on the reduced estimate; and if we could store up two-thirds of the whole fall we might supply the canal with Colonel Cautley's maximum supply during the whole year.

14. Next (still on this first point) I refer to the drainage water crossing the Grand Trunk Road, which runs along the foot of these hills at a distance not exceeding 15 miles. The road has 3 large bridges and 184 drains of sizes; and these have been proved so entirely inadequate to carry off the floods, that large works are still in progress and under estimate for increasing the water-way by many thousand square feet. The bridge over the Kurumnassa River has a water-way of about 5,500 square feet, and is at times so over-charged by the floods, that the water rises over the crowns of the arches and on the up-stream side the water level is variously reported on different occasions as being from 14 inches to 2½ feet above the level on the down-stream side. If the difference of level be taken at 18 inches, the ordinary hydraulic rules would give the mean velocity of the river at 10 feet per second, making the discharge 5,500 cubic feet in a second. That is to say that in a five days' flood there runs to waste, through this bridge alone as much water as would fill our imaginary reservoir to 853 feet deep, or in other words nearly as much as would feed the 200 miles of canal for a whole season. A five days' flood in this river is no uncommon thing, and gives but a small quantity of water compared with the discharge of a whole rainy season; and as the water-way of this bridge is not one-fourth of the whole water-way of the drains and bridges on the road, there appears no reason to fear but that the required quantity of water from the proposed canals is forthcoming.

15. The next question is, can we collect so much water into reservoirs in the hills? That immense bodies of water have been

collected in various parts of India in lakes by throwing dams across valleys is well known. In Ajmere and Mhairwara alone Colonel Dixon has constructed in this way (or found ready constructed) tanks or lakes which when full cover in the aggregate 35 square miles. In the narrow and deep valleys of the Shahabad hills* composed as those hills are of excellent building stone, there appears to be no reason why we should not be able to construct barriers at intervals each forming a lake so as to stop all the surface drainage of the rains, and to collect the discharge of the perennial streams in the dry season. The work would not be expensive, considering its magnitude, because besides the building stone there is lime-stone and plenty of wood to burn it, and we know from Colonel Dixon's rates in much the same construction in Ajmere, and from Captain Knyvett's on the Grand Trunk Road in the Shahabad district, that such work and work in that locality can be done very cheaply. Of course nothing like a definite estimate can be made till the hills have been examined, and the sites and dimensions of the dams fixed upon, but I shall give a rough calculation based on the cost of Colonel Dixon's work further on.

16. The last point for consideration as to the reservoirs is as regards their power of retaining water for a long period. This can only be judged of by examples, and I am sorry that I cannot at present find any examples recorded in sufficient detail to enable me to state the facts in figures. All the large tanks formed by damming across valleys all over India, are known to retain water as a general rule all the year round; and from what I have seen of Colonel Dixon's works I should say that exclusive of the drains on them for irrigation the wastage in a season is not more than 30 per cent.;—that is for the larger tanks: the small tanks of 4 or 5 feet deep of course run dry.

17. I come now to the question of the cost of the entire undertaking. But before proceeding further I would wish it to be understood that I by no means intend, in speaking of 200 miles of canal, that such a length should be constructed at first, even if the scheme appears feasible on close examination. It was necessary, in order to estimate the feasibility of the scheme for irrigating the whole or a large portion of the district, to speak of the water supply on a large scale, and I continue the same scale in going on to speak of the cost.

18. The rough estimate I am now to give naturally divides into three heads :—

1st. Expense of storing the water in the hills.

2nd. Expense of conveying the water from the hills to the plains.

* Vide Captain Sherwill's Descriptive Asiatic Journal, Vol. XVI., para. 1, March 1847, page 279.

3rd. Expense of distributing it over the plains.

19. On the first head I must derive my information from the cost of Colonel Dixon's reservoirs. On the second and third from the Ganges Canal raised estimate of 1850.

The six large tanks Colonel Dixson describes in the greatest detail (not being old works renewed or embanked tanks on low-land) are—

	Names.	Greatest depth of water.	Area in Local Beegahs.	Cost.
1	Kabra	20	450	6,248
2	... ...	28	500	16,550
3	Gohana	24	260	4,270
4	Burrar	36	220	4,000
5	Duratoo	26	1,000	25,995
6	Shreenuger	25	800*	14,649
		Total ...	......	71,602

The two last are in Ajmere local beegahs, 1,936 Sqr. yds.
The rest in Beawar do., 1,764 do.
* Given, by a misprint, 300 in Colonel Dixon's list.

The mean depth of these tanks is not given by Colonel Dixon; but assuming it to be ⅓rd of greatest depth, and reducing the quantities of water thus calculated to the standard of the imaginary reservoir I have before taken as the standard measure, I find that the quantity of water in all six tanks is equal to 16⅔ feet depth of the reservoir, which gives the rate of storing water Rs. 4,300 nearly for each foot in depth of the said reservoir, sluices and escapes included.

20. Turning now to Colonel Cautley's papers, the Estimate of the Ganges Canal may be roughly stated thus :—

6,750 cubic feet of water per second conveyed 24 miles from the hills to the plains, at Rs. 35½ per foot per mile	Rs.	55,68,750
6,750 cubic feet of water per second distributed over the plains, at Rs. 1,275 per foot	"	86,06,250
Total 6,750 cubic feet per second conveyed and distributed, at Rs. 2,100 per foot	Rs.	*14,175,000

21. For the proposed Canals in the Shahabad district the cost calculated after these data will be—

Quantity of water equal to 900 feet depth in a reservoir of 1 mile square collected and stored in the hills, at Rs. 4,300 per million feet ...	Rs.	38,70,000

* Colonel Cautley's detailed Estimate is Rs. 14,619 less than this.

1,600 cubic feet per second conveyed at average distance say of 10 miles to the plains at Rs. 35½ per foot per mile	Rs.	5,68,000
1,600 ditto distributed over the plains at Rs. 1,275 per foot	"	20,40,000
Total 1,600 cubic feet per second stored, conveyed, and distributed at about Rs. 4,000 per cubic foot...	"	64,78,000

This makes the cost of the proposed Canals, in proportion to the supply of water, nearly double that of the Ganges Canal.

22. I have first given the rough Estimate exactly on the entire data of the cited works without attempting to adapt them to the case in hand; but I conceive that views given of the expense is more unfavourable than it should be, because in the Shahabad District there would be the advantage over Colonel Dixon's works of a better field for selection of favorable sites for dams so as to enable us to make them less costly in proportion to the water retained; and over Colonel Cautley's works there would be the advantages of very cheap district for building, of a less difficult country to carry the water over to the plains, and of less distance over which to distribute the water, and therefore smaller and less expensive channels and bridges. Besides these matters I have left out of consideration the very important items of the dry season discharge of the rivers. This I cannot pretend to estimate with anything like accuracy, but as I know the Kurumnassa down in the plains has a discharge of 30 or 40 feet per second, the whole discharge of all the rivers in the hills may perhaps be reckoned at 100 cubic feet per second.

23. Allowing this we should only require to store up 620 feet depth of the imaginary reservoir, in order to supply the 200 miles of Canal.

The work of those Colonel Dixon describes which most nearly suits the circumstances of the Shahabad Hills is the Burra Tank, which cost only Rs. 2,666¾ per foot in the depth to which its waters would fill the imaginary reservoir.

The Etawah branch (or fork) of the Ganges Canal is of dimensions to contain the discharge of the whole of the Canals I propose if taken on one line, that is, it affords about 190 miles of irrigation, and it has locks at its termination to descend to the Jumna. The estimate for it is as follows:—

Earth-work...	Rs.	6,03,869
Masonry	"	7,03,290
Contingencies at 5 per cent.	"	65,357
	Total Rs.	13,72,516

Reducing the cost of masonry to one-half, as per Shahabad rates,* this becomes :—

Earth-work	Rs.	6,03,869
Masonry	"	3,51,645
Contingencies	"	47,775
Total	Rs.	10,03,289

which is about Rs. 660 per cubic foot of discharge per second taking it at 8 cubic feet to the mile before.

The country through which these Canals will have to be carried from the hills to the plains is so much easier than the country the Ganges Canal has to cross that (considering the cheap rate of the district) the cost of that part of work may be taken at one-half of the rate of Colonel Cautley's Estimate.

24. Putting all those considerations together, I give now a lower estimate for the proposed 200 miles of Canals, thus :—

Water stored equal 620 feet depth of a reservoir of a mile square, at Rs. 2,666⅔ per foot ...	Rs.	16,53,000
1,600 cubic feet of water per second carried over an average of 10 miles of hills to the plains at say Rs. 17¾ per foot per mile	"	2,84,000
1,600 ditto distributed over the country, at Rs. 660 per foot	"	10,56,000
Total	Rs.	29,93,000

which is under Rs. 2,000 per cubic foot of discharge per second, and something below the cost of the Ganges Canal water.

25. The first item of this estimate I believe still to be over-estimated; but it will hardly be safe to make any further reduction until the country has been examined. I will only state that from Captain Sherwill's Geological Map and Sketches thereon it appears that one of the valleys (near the Shurgurah Fort) which receives the drainage of 120 square miles of hill country, has a gorge of only a few hundred feet wide, with high perpendicular sand-stone rocks on each side to dam this. To the height of 100 feet would probably not cost Rs. 1,00,000, and the reservoir formed might certainly be made to contain ¼ of the whole required supply for the 200 miles of Canal, and at this rate 4 lakhs instead of 16 would form the first item of the estimate. This shows how greatly the estimate may be reduced if the examination of the hills give favourable results.

* Prices have risen greatly since this was written.—1861.

26. Going on now to the question of returns, I give an abstract of the actual returns of the Jumna Canals on an average for the last five years—

On each cubic foot of the maximum discharge per second.	Western Jumna Canal, maximum discharge 2,000.	Eastern Jumna Canal, maximum discharge 800.
Gross return from water rent mills, rafting timber, &c., of which the water rent is about 85 per cent....	153·4	186·9
Deduct expense in Establishment and Repairs ...	68·1	95·4
Balance net return ...	85·3	91·5

which gives a return clear of expenses of a little more than 4 per cent. on the Ganges Canal Estimate and lower estimate of the Shahabad Canals, and about $2\frac{1}{8}$ per cent. on the higher estimate.

27. The Jumna Canals, however, have not yet attained a degree of employment equal to the full working power of a well contrived Canal. Colonel Cautley reckons that each cubic foot of discharge per second should irrigate 350 beegahs or 218 acres, and the water rent being R. 1 per acre, this would give a gross return of Rs. 218 per cubic foot of discharge, add Rs. 32 for mills, rafting, &c; total Rs. 250; and from this deduct expenses at Rs. 80, being about the average of the Jumna Canals, and there remains a net return of Rs. 170 on each cubic foot of water discharged per second, which is $8\frac{1}{2}$ per cent. on the lower estimate, and about 4 on the higher.

28. But the direct revenue on Canals is not the main thing looked to in the North-Western Provinces. There the chief return is taken to be indirectly in the revenue arising from the increased cultivation of the country. I believe the nature of the revenue settlement in Bengal will prevent any return from the outlay on Canals in the shape of increased land revenue. But if the cultivator cannot be made to pay a fair price for the advantages of the canal from the rent of the land, it is right that he should pay in the way of rent for the water.

29. The irrigation by wells of 10 acres of land requires, according to Colonel Cautley's calculation, the employment of two men and eight bullocks, while the same effect where there is a canal can be produced by one-fifth part of the labour of one lad. The mere cost of the labour employed in well irrigation, therefore 10 acres of land, taking it for two months in the year, cannot be less than Rs. 24 per annum; for the cost of canal irrigation we

have the fifth part of the labour of the boy for the two months not more than R. 1, and the water-rent at R. 1 per acre, Rs. 10; total Rs. 11, or not half the cost of the well irrigation. But besides the difference of actual labour, there is the loss of capital sunk in pucka wells, or the expense of the renewal and repairs of cutcha wells, which are much more costly matters than the constructions and repairs of irrigating channels from the canal.

30. This shows that even in the most unfavourable case, namely, that in which the cultivator has means of irrigating his land, he would gain greatly by the construction of canal, and that he could well afford to pay a much higher rent for the water, if he does not pay increased rent for the land it enables him to improve or bring into cultivation. It appears therefore that the nature of the land settlement in Bengal need be no obstacle to canals being made as profitable an investment of Government Funds in Bengal as in the North-Western Provinces.

31. Again, I find from the printed return that the Shahabad District contains 2,085,561 acres of cultivated and culturable land, and that the revenue assessments is Rs. 13,94,397, that is only 10 annas 8½ pie per acre. The average of the assessment in the North-Western Provinces is Rs. 1-12-11 per acre of cultivated land; so that on a settlement like that of the North-Western Provinces the revenue of Shahabad might be nearly trebled if all the land could be brought under cultivation. This shows to how great an extent it would be worth the cultivators' while to pay water rent for canals.

32. For the Husli Canal in the Punjab the people now actually pay Rs. 2-6-8 per acre for water rent; and from all accounts of the busy agricultural prosperity which follows the introduction of the means of irrigation, in all parts of India, I feel no doubt but that the people would be most willing to pay Rs. 2 per acre for water rent in the Shahabad district as soon as the advantages of the canal come to be fully understood, considering that the cultivators there can be taxed nothing more for the land the canal would enable them to cultivate or to improve.

33. Doubling the Jumna Canal rate of water rent (that is, making it Rs. 2 per acre) would make the return on the proposed Shahabad Canals, estimated by those of Jumna Canals, about 10¾ or 12¾ per cent. on the outlay as per lower estimate, and on the higher estimate from 5⅝ to 6⅝ per cent.; or taking the full working rate as per Colonel Cautley's calculation of the irrigating powers of canals, the return would be 19½ per cent. on the lower, and about 10 per cent. on the higher estimate.

34. I have now stated all I have to say on the prospects of the proposed Shahabad Canals considered merely in view to their chief object, irrigation; and the same advantages may, if the scheme succeed, be obtained on the south bank of the Soane in Behar from the hills in which are the sources of the Fulgoo, Morhur, &c., and also as far as the progress of civilization and

population admits of a prospect of any return in the other Districts all round the same mass of hills, to the valleys of the Damooda and Dalkisore.

35. It may not be out of place here to suggest that if the case be considered made out, that the proposed Shahabad Canals have a fair prospect of yielding a good return, a similar or perhaps a better return would, in all probability acrue from the construction of a canal with a river supply obtained from the Gunduck* in the Sarun and Tirhoot districts. The British dominions extend sufficiently far up the stream of the Gunduck to allow of a good head of supply. The south parts of these districts frequently want water, and the lower part of the Canal would be a great boon to the Tirhoot planters, and proportionally profitable to Government. I speak of course only from general knowledge, and subject to correction after a detailed examination of the river and districts.

36. Next to the irrigation of the crops in ordinary seasons, the canal requires consideration as a means of guarding against the evils of drought. Until the possibility of retaining the water at a reasonable cost for one season is fully made out, it would be premature to reckon on retaining it so long as to secure the country against the danger of famine from the failure of a season's rains. But granting that from a moderate season's rain water could be laid up in the reservoirs so as to suffice for the irrigation of the crops for the succeeding dry season, and that we could afford room in the reservoirs for more water, I think the excess of water in years of more than ordinary plenty might be retained for years of deficient rains. The greater the quantity of water collected, the smaller is the proportion of the wastage by evaporation and absorption to the whole, so that any excess remaining in the reservoirs at the conclusion of any one dry season would not only be an addition to the next season's supply, but would have the effect of diminishing the percentage of the next season's waste, and thus would cause an accumulation from year to year so long as the fall of rain was not much below average. Besides this we have the chance of the not uncommon occurrence of rain falling plentifully in the hills when very little falls in the plains. But it must be confessed that Canals fed by reservoirs to be filled by rain are very inferior to Canals fed by perennial rivers as preservatives against famine.

37. The advantages of navigation would of course be to a great degree obtainable from these Canals; but unless the supply of water proves to be very ample for irrigation, it will not be prudent to attempt to carry the navigation down to the Ganges. Could this be done however the Canals, besides allowing of the cheap transport of fire-wood, timber, and building materials, and also iron ore to the valley of the Ganges, might be made the means of conveying coal from the Palamow and Singrowlee Coal fields, as also possibly from Kurhurbalee and other parts. Reservoirs might be established in

* Perhaps also from the Koosee to the east of Tirhoot.

the plains to relieve those in the hills of the expense of lockage for the descent into the Ganges, and additional reservoirs would have to be constructed from the part of the Canal carried back through or round the hills to the coal basins. The Engineering difficulties of this latter operation would be obstacles to bringing the Canals into use for the transport of coal; but with so great an object in view, the obstacles should not be considered insurmountable. Considering how much of the expense of the Canals will be paid by irrigation, this means of transport will probably be found cheaper than any other.

38. A most important advantage in the scheme of Canals I propose on, which is almost peculiar to it, is in regard to the floods to which the districts bordering on the hill tracts in Bengal and Behar are liable. If the system of reservoirs for arresting the rain water in the hills were universally introduced, these floods now so destructive and difficult to control, would be stopped at their fountain head. All the difficulties in regard to embankments would be at an end, and the waters now wasted, and by which so much damage is annually done, would become the means of increasing the fertility in the dry months of the very plains which before they covered with devastation in the rainy season.

39. In the early days of such countries, when the population was thinly scattered and the people rude, the floods from the hills pour down upon the plains, and cover them with fertilizing deposits; but when the plains have become fertile, and the population thickens, and the people increase in civilization, the floods become injurious, and should, if possible, be restrained. The hills still serving a purpose of usefulness should then become the platform on which to place the apparatus of feeders and reservoirs by which to water the plains below in the dry season.

40. The last point of view in which I shall urge the advantage of this scheme of Canals is as a means of instructing the natives of the country. The effect of an example of practical science applied to such purposes as will be best understood and appreciated by the people of the districts, must do much in educating the general intelligence of the community. There is more in a Canal to excite curiosity and stimulate the desire of instruction than there is in roads, bridges, or any sort of mere buildings, and though not so striking an example of applied science as a Railway, the application of a Canal being to purposes more interesting to native agriculturalists will make it a better example for them.

41. The matter I have now brought forward is not intended as proof of the practicability of the scheme I have proposed, but only as a *primâ facie* view, which appears to me sufficiently promising to demand a detailed Engineering (and agricultural) examination of the country particularly referred to. And should this examination prove satisfactory, an experiment on a small scale might be made, such, for instance, as a Canal 10 or 15 miles long to bring

down water from the hills for the crops immediately round the town of Sasseram and for the use of the town. The crops round a large town are generally of greater value than those far out in the country, and to irrigate them would give a better prospect of a good return for the expenditure on the Canal, while at the same time the eclât of supplying a large town with abundance of water in a new way would go far to excite an interest in such undertakings, and makes the whole scheme popular in the district.

42. The valleys in the Shahabad hills which are the most important for this project, form two clusters, the gorges of one cluster uniting close under the Fort of Shergurh, and of the other four or five miles east of Chynpoor. The gorges of the remaining detached valleys would form the sites of reservoirs sufficient to feed short Canals to irrigate portions of the country near the hills, and larger reservoirs, or systems of reservoirs, at the gorges of the two clusters would supply Canals leading 50 or 60 miles into the plains, curving towards the Kurumnassa and Ganges, and not carrying the irrigation much beyond the junction of these two rivers. Further extension of the irrigation would depend upon the possibility of bringing the flood-waters of the upper portion of the Kurumnassa across the hills into these two main clusters of valleys, so as to augment the supply from the reservoirs established in them. The water of the lower portion of the Kurumnassa within the hills and of its tributaries in the Mirzapoor district appear to be the property of the Mirzapoor and Benares districts, except so much of the water of the Kurumnassa as could be made to flow in a Canal along the right bank of the river as far as the junction of the Doorgowtee.

43. Without the results of a survey of the country made for the purpose, it is useless to enter into further details of the probable positions of the dams and reservoirs, or of the facilities or difficulties which are likely to be met with in conveying this water to the proper points of discharge upon the plains, or of the directions and lengths of several Canals and branches. The object of the present paper is only to state the project generally, and to point out the district in which I conceive it can best be tried.

I have, &c.,

19*th January* 1853. C. H. Dickens.

From the Under Secy. to the Govt. of Bengal, to Lieut. C. H. Dickens,—*No.* 137, *dated Fort William,* 5*th February* 1853.

Sir,—I am directed by the Most Noble the Governor to acknowledge the receipt of your letter of the 25th ultimo, enclosing a note on a project for canals chiefly for irrigation in certain dis-

tricts under this Government, and to convey to you His Lordship's acknowledgments for this able paper, the subject of which he desires me to assure you will not be lost sight of.

I have, &c.,
J. W. DALRYMPLE,
Under Secy. to the Govt. of Bengal.

Extract from a Despatch from the Hon'ble Court of Directors, to the Govt. of Bengal, in the Revenue Dept.,—No. 9 *of* 22*nd March* 1854.

PARA. 8. We have perused the able paper on Canal Irrigation communicated to you by Lieutenant C. H. Dickens, and as its subject is one to which we attach the greatest importance, we trust that the suggestions contained in it will not be lost sight of.

REPORT OF 1855.

From Captain C. H. Dickens, *late on special duty in Shahabad, to the Secretary to the Government of Bengal.*

Calcutta, 22nd June 1855.

Sir,—In continuation of my letter dated Tilothoo, 22nd January 1855, I have the honour to state that I closed my survey of the Shahabad district at Sasseram on the 23rd April, and returned to Calcutta on the 30th idem.

2. As it will take some weeks to plot my lines of levels and prepare the drawings necessary for the full elucidation of my investigations, I beg now to furnish a Report of the general results of my survey, in which I shall give as much as possible of the information I have collected, noticing the points on which I cannot speak precisely till the drawings are prepared.

3. I have not attempted to collect detailed information as to the quantities of land under cultivation, and bearing each distinct kind of crop in different parts of the district, or in the whole district. To have made a complete investigation of this kind would require much more time than I had to give to the whole enquiry, and I conceive would have no practical value beyond that of the general information I have to give, which was obtained as follows:—

We (myself and two Native Levellers) levelled over above 800 miles of country, besides passing to and frò in order to take up new lines of levelling and for other purposes. As we levelled we measured the depth of all the wells within convenient distances (or at least of a sufficient number when they were numerous), and noted the depth of water in each. We observed generally the state of the crops; we enquired of the people concerning them, and particularly of the labour, cost, and effect of irrigation, and we compared their replies with our own observations. I also obtained information from the Collector's Office at Arrah on the same subjects.

4. Bearing in mind that canals in the North-Western Provinces are considered to be in full work when they afford irrigation to $\frac{1}{3}$rd of the actual surface of the country within reach of which the water is brought, I think the following particulars will be found sufficient satisfactorily to establish the good prospects of the project under discussion.

5. Excluding the hills and the jungles bordering thereon, about $\frac{5}{6}$ths of the Shahabad district appears to be under cultivation, and perhaps $\frac{2}{3}$rds bears spring crops. About $\frac{2}{3}$rds of the spring crops are irrigated more or less. The portions not irrigated are the rich *Khadir* land near the Ganges, of which the Arrah and Buxar Road forms nearly the south boundary; some parts of the country near the lower part of the Koodra where the water is near the surface; the high ground near the hills, where the depth of the water below

the surface is too great to allow of wells being dug, and certain parts of the district, where the people assert they have not time to do the work, but where I suppose they are too indolent to take the trouble.

6. The people appear to depend most on the rice crop, which is cultivated in favourable seasons, with very little trouble, and they will not bestow upon the spring crops the labour which, with the means of irrigation at command, is necessary to bring them to perfection.

7. The irrigation of the spring crop is for the most part effected by drawing water from wells by means of bullocks and the leather bag called a *moth*. In some places, where the water is near the surface, the weighted lever (*lāt*) is used, but it is a more expensive mode of raising water than by the bullocks and *moth*, except where the depth of the wells is very small.

8. There are in some places reservoirs of water for irrigation formed by throwing dams across the small rivers and across nullahs or hollows on the slopes of the hills. The surplus water is allowed to escape round one flank of the dam. The only large reservoir of this description I saw was across the Kao near Bikramgunj. It has a dam nearly three-quarters of a mile long, and 16 feet high in the centre, and was said to have been constructed under the orders or with the assistance of the Collector. The Kao is stated to be dammed in 13 other places, but on a much smaller scale. There are also tanks supplied from channels dug to the larger hill streams (Soora, Doorgowtee, &c.), so as to be filled when the streams are in flood. All these reservoirs are used principally for the rice cultivation, and are generally exhausted before they can be used for the spring crops, or at least after the first watering.

9. I return now to the irrigation from wells by means of the bullocks and *moth*, as being the method most generally employed for the spring crops, and from which therefore I calculate the value of irrigation in the dry season.

10. The wells are not deep, reaching generally from 18 to 28 feet below the surface: on the average perhaps 22 feet. But the supply of water is in most parts of the district scanty, and little more than a foot remains in the wells while the *moth* is in use.

11. To irrigate the crop the water is run through the fields in channels, whence it is sprinkled over the crop with wooden scoops. This mode of irrigation is very inferior to that practised in other parts of India (and for opium in Shahabad) of allowing the water to submerge the whole field plot by plot.

12. With wells of the average depth the irrigation requires two pairs of bullocks (to work and rest by turns) and two men at the well, besides a woman or boy in the field to form the channels and sprinkle the water. On an average one *moth* will water about $\frac{3}{5}$ths of a beegah ($\frac{3}{8}$ths of an acre*) in a day. A

* The beegah of 3,025 square yards is used in Shahabad.

labourer who has received an advance of money from his employer gets $2\frac{1}{2}$ or 3 seers (5 or 6lbs) of one of the cheapest kinds of grain as his daily wages; value about 3 pice of 20 or 21 *gundas* (or fours) to the Rupee, (that is 80 to 84 to the Rupee, 40 to 42 pice to a shilling). A labourer not in debt is allowed 4 seers of grain, value about 4 of the pice current in the district, or $\frac{3}{4}$ths of an anna of the Company's coinage ($1\frac{1}{8}$ penny) as his day's wages. I was not able to form a satisfactory direct estimate of the cost of keeping up the bullocks and their gear with the *moth*, but I found the established rate of hire for the two pairs of bullocks with gear and moth is 4 annas (6 pence) a day. The cost to the proprietor would, I suppose, be something less. I therefore set down the cost of one day's irrigation from wells.

	RS.	A.	P.	£	s.	d.
2 men	0	1	6	0	0	$2\frac{1}{4}$
1 woman or boy, omitted, being also required for canal irrigation, ...	0	0	0	0	0	0
Bullocks and *moth*	0	3	6	0	0	$5\frac{1}{4}$
One day, or to water $\frac{3}{5}$ths of a beegah, $\frac{3}{8}$ths acre	0	5	0	0	0	$7\frac{1}{2}$

To water a beegah once, therefore, costs... ...	Rs.	0	8	4
And acre	£	0	1	8

13. The greater part of the spring crop is watered only once or twice in the season, but some of it three times, particularly wheat. Wheat in some few places is watered four times. Where the irrigation was industriously applied, I generally found the rule to be to water barley twice and wheat three times. The excuse for not irrigating more in places where the above was not acted up to was more frequently want of *time* than want of *water*. I am inclined to think the real cause is often indolence rather than scarcity of labour. But for either case the supply of canal irrigation affords a remedy, as it saves both labourers and trouble.

14. Excepting in the rich land near the Ganges and a few other favoured spots, the unirrigated crops of wheat and barley are very scanty, and are said to produce only from 2 to 6 maunds of grain per beegah (256 to 640 lbs. per acre), and those irrigated once or twice yield only from 4 to 8 maunds (512 to 1,024 lbs. per acre). Irrigated three times the crop is said to yield from 7 to 10 maunds (896 to 1,280 lbs. per acre); but the people told me if they could irrigate 4 times, using abundance of water, they would get from 10 to 15 maunds of grain per beegah (1,280 to 1,920 lbs. per acre).

15. Colonel Cautley states the produce in the Seharunpoor and Bolundshuhur Districts to be about $8\frac{1}{2}$ maunds per beegah for unirrigated, and 13 maunds for irrigated land (1,089 and 1,702 lbs. per acre). There is certainly a very much greater difference than

this in most parts of Shahabad; and allowing for some exaggeration in the native account above given, I think the supply and use of abundance of water to irrigate the crops would double the produce of the greater part of the district.

16. Watering 3 times in the imperfect way above described, cost as above shown about Rs. 1-9-0 per beegah (5 shillings an acre) for the season,* and it is evident that the money is well laid out. Doubling the rate of water rent levied in the North-Western Provinces (that is charging Rs. 1-4-0 instead of Rs. 0-10-0 per beegah), 4 shillings instead of 2 per acre, we should be able to supply the cultivators with irrigation 25 per cent. cheaper than they get it now, and in addition give them all the advantages of 4 thorough drenchings for their crops instead of 3 sprinklings. They will besides have the canal supply of water all the rest of the year without any further payment, and will be able to turn it to more profitable account in raising more valuable crops than the wheat and barley, which alone I have calculated upon.

17. I found the water bags used in Shahabad hold on an average about $2\frac{3}{4}$ cubic feet of water. They were worked for short periods at the rate of about 25 per hour, but that was not kept up throughout the day, and the total number raised daily was said not to exceed 150. To be sure of making a liberal calculation I shall, however, take it at 300. This therefore I take as the bulk of water required for $\frac{3}{5}$ths of a beegah ($\frac{3}{8}$ths of an acre) for one watering. For a whole beegah this gives 500 bags (800 per acre) for one watering, and 2,000 (3,200 per acre) for four waterings, or a full season's irrigation. But this is for the imperfect kind of irrigation practised in Shahabad. To irrigate thoroughly I shall suppose double the quantity of water necessary, that is 4,000 bags or 11,000 cubic feet per beegah (17,600 cubic feet per acre).

18. The irrigating season in Shahabad commences about the beginning of November and terminates at the end of February. It lasts, therefore, about 120 days. Now one cubic foot of water per second for 120 days is 10,368,000 cubic feet, which will water 942 beegahs or 588 acres. But this is the supply to be delivered from the canal, and it is necessary to add to it the quantity required to make up for the wastage in passing down the channel, in order to determine the discharge required at the canal head.

19. There are no data for ascertaining the loss from evaporation, soakage, leaks, and thefts of water on our Indian Canals. I

* Lieut. Col. Baird Smith (page 381, Vol. I., Italian Irrigation) makes it (omitting interest of capital) £1-11-$2\frac{3}{4}$. He has, however, calculated the hire of the men and beasts for the whole year, while my calculation extends only to the period of irrigating the spring crops. Taking the irrigating season at 4 months or $\frac{1}{3}$rd of the year, the rate comes to £0-10-$4\frac{3}{4}$. The difference between this and my estimate may be owing to the greater depth of wells and the more liberal scale of irrigation. But the wages and cost of bullocks differ greatly from those in Shahabad.

[See also the Extracts given at the end of this Appendix. 1861.]

am obliged therefore to refer to the examples of Italian Canals given in Captain (now Lieutenant Colonel) Baird Smith's work on Italian Irrigation. They are as follows:—

Page of Volume I.	Name of Canal.	Total discharge cubic feet per second.	Loss in cubic feet per second.	Percentage of total discharge.
116	Caluso	440	90·65	20·6
224	Naviglio Grande	1,851	158·25	8·6
254	Muzza	2,652	477·	18·0
276	Martesina...	843	105·	12·4
	On the whole	5,786	830·9	14·3

From this I infer that even in the dry climate of Shahabad we ought by good management to be able to [illegible] the wastage under 20 per cent. Deducting this proportion it a[illegible]rs that each cubic foot per second of the discharge at the canal head ought to supply irrigation for 754 beegahs (or 470 acres), something less than ¾ths of a square mile.

20. In practice in the North-Western Provinces it is, however, found that each cubic foot of the discharge will not irrigate on the average more than 350 beegahs (218 acres), or little more than ⅓rd of a square mile. Even making a large deduction for the imperfections of the canals, it still appears that the canal water in the North-Western Provinces is very wastefully applied by the cultivators. With the view of inducing economy in the use of the canal water contracts for letting the discharge from established openings were entered into on the Western Jumna Canal when under the superintendence of Lieutenant Colonel Baker, so as to levy the water rent on the quantity of water supplied instead of on the area of land irrigated. But to carry out this principle in full it is necessary to have some uniform and accurate system of measuring the discharge of water from each outlet. This matter has for some time engaged the attention of Lieutenant Colonel Smith, who is about to establish *Modules* according to the Italian system on the Ganges Canal, and levy water-rent in proportion to the discharge measured by means of these contrivances.

21. Anticipating the success of this plan, I may I think calculate that each cubic foot of water supplied per second will

irrigate 512 beegahs (320 acres) or ½ a square mile,* and following the Ganges Canal Committee, I shall suppose one-third of the gross area of the flat portion of the district, excluding the Ganges Khadir land, will need to be supplied with irrigation, or that 2 cubic feet per second must be supplied for every three square miles of the gross area.

The sources of supply are—

(1). Reservoirs to be formed in the valleys where the hill streams issue into the plains.

(2). The Soane.

22. In regard to the first source of supply, I have to state that as far as I could ascertain (there being no regular register) the rain fall in the hill tract of Shahabad does not exceed 36 inches per annum on an average. Judging from the data given for supply reservoirs for towns in England, I suppose we may calculate on being able to collect ⅔rds of the rain fall, that is to say,—$2 \times (5280)^2 = 2 \times 27{,}878{,}400 = 55{,}756{,}800$,—55 millions of cubic feet per square mile of gathering ground.

23. A supply of one cubic foot of water per second for the whole year is equal to 31,536,600 cubic feet, and this is sufficient for 1½ square miles. Adding 50 per cent. for soakage and evaporation in the reservoir, the quantity to be collected for the purpose is equal to 47 millions of cubic feet, or for each square mile of the gross area of the district to be irrigated 31½ millions of cubic feet.

24. The rivers from which the reservoirs are to be filled are subject to very violent floods, which do great injury to the crops, but their more moderate floods are highly beneficial, and are made the source of supply of tanks for the rice cultivation by throwing dams across the rivers themselves, or across channels lead from them into natural or excavated hollows.

25. I think it will therefore be right not to attempt to detain the full quantity of water drained from the hills, but using the reservoirs as regulators to let portions of it escape into the rivers from time to time during the rainy season, as it may be required for the rice crops.

26. I have taken therefore the land to be irrigated from the reservoirs as about equal to the gathering grounds. This allows in each square mile of drainage—

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* Since writing the above I have seen Lieutenant Colonel Smith's calculation appended to his draft of new rules for the distribution of water. For spring crops he allows 4 waterings of 3 inches each, or in all one foot spread over the surface, which gives 43,560 cubic feet per acre in 130 days, whence, making no deduction for loss in the canal, a cubic foot per second is considered adequate to water 360 acres of spring crops for the season.

	Cubic feet.
To be stored for the supply of the Canals...	31,500,000
To be let off for the rice cultivation... ...	24,256,800
Total ...	55,756,800

27. This I believe the cultivators will receive the full benefit of their own tanks in addition to the canal supply all the year round. But if there be any deficiency, the latter may be reduced during the season when water is least required.

28. I apprehend, however, that the supply of water calculated will be found ample, and that a considerable saving may be made by reducing the expenditure of water at the seasons when it is not much required, so as to accumulate from year to year an increased supply of water for use in case of dearth. I have therefore added extra reservoir room to the extent of 27 per cent., making the whole storage room 40 million cubic feet per square mile of land to be irrigated.

29. From this should be realized water-rent at Rs. $1\frac{1}{4}$ per beegah for $\frac{1}{3}$rd of the area to be irrigated (or $\frac{1024}{3}=341\frac{1}{2}$) beegahs, being Rs. $426\frac{2}{3}$ per annum (or four shillings per acre on $213\frac{1}{2}$ acres, £42-13-4). Setting aside half of this for establishment, current expenses, and ordinary repairs, the other moiety will at 5 per cent. represent a capital of Rs. 4,266-10-8 (£426-13-4) to be laid out on storing water for each square mile, according to which calculation the maximum remunerative rate is Rs. 106-10-8 (£10-13-4) per million cubic feet. In the Madras Presidency the ordinary rate appears to be Rs. 40 (£4) per million cubic feet. Colonel Dixon's rates in Mhairwarrah amount to Rs. 150 for the principal tanks, but they have masonry dams, while in Madras the dams are generally of earth. From such rough calculation as I have been able to make without complete sections, I believe we shall be able in favourable sites in Shahabad to store water for Rs. 25 or 30 the million cubic feet; but for an extensive system all the sites, both favourable and unfavourable, must be occupied, and I do not think the average rate can reasonably be expected to be under Rs. 50. I set it down at Rs. 60 for the present.

30. The levelling in the ravines and jungles near Sherghur occupied so much time that I was unable to make as complete an examination of the sites for reservoirs as I wished. I believe, however, I shall be able to give tolerably accurate estimates of the cost of storing water at the Tootla Koond (west of Tilothoo), the Dhooa Koond (south of Sasseram), and the Doorgowtee Valley at Sherghur. I also took sections of the gorges from which the Soora and Kora Nuddees issue, and satisfied myself, by taking a few vertical angles with the theodolite, that the lower parts of the valleys

have a very gradual rise, and are well suited for the formation of reservoirs. I was unable to visit the Valley of the Kurumnassa or those of its tributaries from the west.

31. The most important of the sites for reservoirs or systems of reservoirs is the many-branched Valley of the Doorgowtee above Sherghur, which carries the drainage of 275 square miles of country through a gorge not a mile wide between the Sherghur Fort and Raja Deo's Peak. The plains slope up to the mouth of this valley, where they attain a height of 370 feet above the level of the sea, and form as it were a *bar* of stiff clay across the gorge through which the Doorgowtee cuts a channel of 85 feet deep. The interior of the valley close to Sherghur is only 325 feet above the level of the sea, and it does not attain the height of 370 feet for six miles further up, so that it is only necessary to dam the river channel and stop some nullahs to pond the water up for the distance of six miles. The valley, however, is narrow, never exceeding half a mile wide, and in places contracting to one-fourth of a mile. It is surrounded by sand-stone hills from 5 to 800 feet high, consisting of a steep slope for one-third of their heights, surmounted by a precipice, above which is the table-land. A reservoir formed here would have a capacity of about 1,000 million cubic feet. Another very good site for a reservoir is in the Kudhur Khoh, where a dam of 70 feet high in the centre, and about 700 feet long in all, will retain about 700 million cubic feet of water. But the joint capacity of these two reservoirs is not one-sixth part of what is required fully to make use of the drainage of the Doorgowtee. To make full use of this drainage, it will be necessary to occupy every branch of the valley, as well as the excellent sites afforded by the great mass of deep ravines which exist around the Doorgowtee for the first 10 miles of its course through the plains, where its channel is from 80 to 40 feet deep.

32. The Dhooa Koond is a deep valley, a mile and a half long, by three furlongs wide at its mouth, situated about four miles south of Sasseram. At its upper extremity is a water-fall (of about 150 feet), by which a stream having a drainage area of about 24 square miles descends from the table-land. Opposite the mouth of the valley is a small detached mass of hills, and the river divides into two, one part passing to the left goes through Sasseram, and under the name of the *Koodra* joins the Doorgowtee a little above the junction of the latter with the Kurumnassa, while the other passing to the right becomes the *Kāō* and proceeds to join the Ganges near Bhojpoor. The adjustment of the levels of these two branches of the stream from the Dhooa Koond is maintained by the Koodra branch passing through a rocky pass and the Kāō over a very stiff bed of clay. Both are within two miles of the water-fall.* The clay appears, however, to be wearing away slowly, and the flow of the Koodra, which car-

* The stream has only 4 feet of slope from the foot of the boulders below the water-fall to these obstructions.

ries off only about one-fourth of the water, is said to be reducing annually. The division of the stream has long been a source of disputes, and it is said that on one occasion the attempt of the Zemindars of the east to dam up the channel of those of the west led to blood-shed. The remains of the dam still exist. A very large reservoir with two openings (east and west) might be formed by including with the Dhooa Koond Valley the space between it and the detached mass of hills; but this would have the inconvenience of closing the present road from Sasseram to Tilothoo. I am disposed therefore to recommend a smaller reservoir, including the valley only, and to form others lower down, both to the east and west. The Dhooa Koond reservoir may be made to hold 2 or 300 millions cubic feet, and the others should contain on the whole about 100 millions more. These reservoirs may I believe be constructed at a very moderate cost.

33. The Tootla Koond has a smaller valley than the Dhooa Koond, and a smaller drainage area, only 6 square miles, but the water fall is higher, being 220 feet. The valley unfortunately has a very steep ascent, and I fear it will be impossible to form a sufficiently large reservoir in it to contain the whole available discharge of the stream, 276 millions cubic feet; but I believe it will be found practicable to form reservoirs on the upper slopes of the plain to hold the surplus which the head reservoir will not contain. The reservoirs here will be more expensive than those of the Dhooa Koond.

34. When I prepared the Memorandum of my original project for affording irrigation in Shahabad, I had not seen the Soane, and from the current reports concerning it, expected to find the supply of water in the dry season very scanty and unimportant for irrigation purposes. I also supposed that the level of the dry season stream would be found too low, the country between the river and the Kymore Hills too difficult, and the immense width of the sandy bed of the river too great an obstacle to make it worth while to attempt to obtain the use of this supposed small supply of water for irrigation. I therefore made no mention of the Soane in my Memorandum. Major J. Laughton, of Engineers, after reading the draft of my project, suggested the Soane as a source of water supply for Shahabad; but he did not appear to be sanguine as to the capacity of the dry season stream, and had then no knowledge of the country between the river and the Kymore Hills. I hoped he would have been able to give his attention to the subject on his return to the North-Western Provinces; but I suppose he had not time, as I heard nothing from him on the subject.

35. I have already reported in my letter of 22nd January how greatly the discharge of water from the Soane exceeded my expectations. I have now to add that it had not been less than 4,000 cubic feet per second up to the date of my leaving the district, as will appear from the following Table :—

Dates.	Discharge by whom determined.	Cubic feet per second.	Remarks.
1855.			
8th January.	Captain Dickens	5,750	
1st February.	Sergeant Bingham	4,624	
1st March ...	" "	11,020	A flood occurred on 27th February.
20th April ...	Section by Sergeant Nolan	4,350	Discharge calculated from Section.

36. I also reported in the letter above referred to that I had found the country between the Soane and the Kymore Hills below the junction of the Koel to be of such a nature as to render the construction of a canal channel from Bandoo to Dehree quite practicable. The circumstance of a strip of country, generally not more than 5 miles wide, lying between a large river and a wide range of hills, upwards of 1,200 feet above it, being so little cut up by water-courses, is remarkable, and appears to be owing to the fact that the portion of the table-land bordering on the Soane is the highest, so that the drainage, with little exception, falls away from the Soane to the Kurumnassa and Doorgowtee.

37. Including the detached hills east of Sasseram with the Kymore Range, the strip of country between the hills and the Soane may be considered to commence (from the north) at the Grand Trunk Road. Proceeding up the Soane (south) no low *(Khadir)* land is met with for the first 20 miles.* The drainage for the first 15 miles is away from the Soane; of the first five miles at the northern extremity, part of the drainage falls into the Kāō, and part into a nullah which joins the Soane, and that of the rest of the 15 miles into nullahs which join the Tootla, and so eventually reaches the Soane at Tilothoo, nine miles from the Trunk Road.† The next five miles having a drainage towards the Soane through several nullahs, the largest of which is spanned by a 22 feet arch, brings us to the *Khadir* land, which extends from three miles north of Akberpoor to one mile west of Bandoo, being about 11 miles long, and in very few places more than 1½ miles wide. The Hoosenee Nuddee leaves the high ground and passes through the Khadir at Akberpoor. The Khadir land is terminated by a rocky hill which juts into the Soane just above the narrowest part of the river at Bandoo. Not far above this is another rocky hill opposite the junction of the Koel. Between these two hills and the Kymore range the flat country rises considerably and falls again higher up the Soane, so that it would be difficult to carry a canal to Dehree

[* There are two small strips: one east of Tomba, and one south of Dehree.—1861.]

[† This needs some correction in details: see Report of 1861.]

from any point of the Soane much above Bandoo; and the difficulty is increased by the country being very much cut up by nullahs.

38. In the first line I levelled from Dehree to Bandoo, I met with three difficulties which I shall notice in the order of their occurrence in returning, or going down stream. From Daranuggur to Shahpoor I met with high land, which would require deep cutting for the canal channel. This I have avoided in the new line by keeping to the Khadir land. In my first line I found the Khadir land I passed through near Akberpoor at the crossing of the Hoosenee Nuddee too low, being liable to inundation when the Soane and Hoosenee are in flood at one time. This may be avoided by taking a line nearer the hills, but it involves some rather deep cutting, as the ground is very uneven. The third difficulty was the passage of the Tootla, which I had crossed where its channel is enlarged by the junction of the nullahs carrying the drainage of the country right and left. By crossing higher up the new line avoids these, and the Tootla aqueduct will be a comparatively small work.

39. The width of the Soane across the flood stream between the Villages of Khabra on the right and Bandoo on the left bank, I found to be 5,978 feet. The greatest depth of water at the time I crossed (11th April) was seven feet, and the greatest depth at flood appeared to be 24 feet. On the Shahabad side (at Bandoo) rocks occur in the bank and extend to a small distance (110 feet) into the river bed. From such examination as I could make without borers, I believe the remainder of the bed will be found to consist of sand to a very great depth. On the Behar side (at Khabra) there is a high kunkur mound or small hill which runs back into the country at right angles to the river, and is far above the reach of the floods; but the bank at Bandoo is only just above the flood level, as pointed out to me, and it may be necessary to construct an embankment above the canal head to a rocky hill which juts into the river about a mile higher up.

40. The Dam or *Annicut* across the Soane at Bandoo will have a length of about 6,000 feet, with a foundation (excepting a small portion at each end) resting entirely on sand. From the practice of the Madras Engineers, it appears that wells sunk to a depth of 10 feet below the bottom (in this case 17 feet below the dry season's water surface) will afford a sufficiently secure foundation, provided a wide platform be constructed below the dam. I believe the work may be built for Rs. 100 or 120 the running foot, or 6 or 7 lakhs in all. Half this expense will be chargeable to the Canal for the irrigation of Behar, should such a work be ordered.

41. It thus appears that there will be no difficulty in carrying the water of the Soane to Dehree, whence its distribution over the district must be considered in conjunction with that of the supply from other sources. But I must first remark that the people

of the district have a prejudice against the use of the Soane water for irrigation, in support of which they refer to the petrifying properties of the water; and it is asserted that since the last severe floods, it has been found impossible to raise sugar-cane near Arrah. But this prejudice appears to have no solid foundation, and as far as my observations go, is most accurately disposed of by Dr. Buchanan (about A. D. 1811) in the passage of his Report on the District of Shahabad, extracted in the margin; and to his remarks I may add that the formations of mud which occasionally take place amongst the sands of the Soane are almost always cultivated when the waters recede after the rainy season.

"They (the floods) are always supposed to do injury, and in fact often overwhelm the crops of rice. This seems to have led to an opinion that the water of the *Soane* River is highly destructive to vegetation, which is very generally asserted and believed throughout the district. This quality of the *Soane* water was so often and universally insisted upon that I began to be staggered, when on the upper part of the river's course I discovered some industrious persons watering their lands (from the Soane) with the utmost success, though the soil is very poor. Martin's Eastern India, Vol. I., pp. 396—7."

42. For the distribution of these various sources of supply of water, according to their several capabilities, the general levels of district appear most favourable. The result of my levelling operations cannot be accurately shown till the complete drawings have been made; but to give a general idea of the slope of the country, I have sketched contour lines on the accompanying map, by tracing on the Revenue Survey Map the villages noted in my Field books. These lines are sufficiently accurate indications of the levels of the country to show the facility of affording irrigation, and particularly from the Soane Canal at Dehree, which will be the chief source of supply.

43. The distribution of the sources of supply is shown on the map by the shades below noted, and the number of square miles to be irrigated from each is as follows:—

Rivers and Reservoirs.	Colour on the Map.	No. of square miles.
Kurumnassa	Yellow ...	150½
Kora and Soora	Green ...	204
Doorgowtee	Pink ...	287
Dhooa Koond and Reservoirs near Sasseram...	Blue ...	102
Soane	White ...	2,037
Total	....	2,780½

The rough calculation of the areas of drainage and irrigation is shown on a separate sketch map. The drainage of the Kurumnassa is omitted, as the Shahabad district will draw little upon it compared with Mirzapoor and Benares.

44. I have now to notice the use which may be made of the contemplated canals as navigable channels, and particularly with reference to the valuable products of the hills to the south of the Shahabad district, on both banks of the upper part of the Soane.

45. *Fuel* from the jungle wood in the hills is an article for which a cheap means of transit to the large cities of Benares, Ghazeepoor, Arrah, &c., is most desirable, and which will no doubt be carried largely on the canals.

46. *Building stone* may also be reckoned as an article for which the navigation will be much used, the quality of the stone in the Shahabad Hills being quite as good if not better than the Chunar stone.

47. *Lime-stone.*—There is in these hills a large quantity of very hard dark grey lime-stone which takes a good polish. It is valuable—

1st. As a source of lime for mortar.

2nd. As a paving marble.

3rd. As metal for roads where kunkur is scarce, or in supersession of kunkur.

48. *Iron* has been largely worked in former days in the Shahabad Hills, as is evident from the great quantities of slag to be found at the gorges of the valleys. There are no works now (except at Soorkee, which I did not visit), and the natives attribute the slag to the remains of the workshops of the giants (*Asur*). I found a good deal of scattered iron ore, and in one or two places observed it piercing the sand-stone in veins; and though I had not time to make any such systematic examination as to enable me to say whether there is any prospect of success for iron works on the large scale on the English plan, I am satisfied that small smelting furnaces, such as are used on the Continent of Europe, might be worked to advantage in Shahabad. On the right bank of the Soane there is a large quantity of excellent iron ore, of which I received many specimens when at Benares some years ago.

49. *Coal.*—The coal of the Palamow and Singrowlee Fields is the nearest to the North-Western Provinces of any yet discovered in India. It has hitherto been very moderately brought into use, owing to the heavy land carriage and the difficult navigation of the Soane. This coal would no doubt furnish large employment to any safe and direct means of water carriage, particularly now that there is a prospect of the immediate construction of the Railway in the North-Western Provinces.

50. The above will be sufficient to show that the canal from the Soane will be very useful for navigation as well as irrigation. But I am persuaded it will also be worth while to construct a canal solely for navigation to carry the coal and other products of the

hills from the Soane Canal near Sasseram to the Ganges between Benares and Chunar.

51. It is stated by Dr. Hooker (Journal, Asiatic Society, October 1848) that the water of the Ganges at Benares was determined by Prinsep to be 300 feet above the level of the sea, the same as the elevation of the Soane at Dehree, determined by Dr. Hooker himself. The latter altitude is, I believe, very accurate;* but if so, the Ganges at Benares is by my levels only 173 feet above the level of the sea, being 127 feet lower than the Soane at Dehree. This difference of level makes the construction of the navigable canal, proposed above, a much less simple matter than I had hoped to find it before I took the levels. But still I believe it will repay the cost, and it is at least worth while to frame a rough estimate.

52. The following are therefore the works which I am prepared to recommend, and for which, with His Honour's sanction, I shall submit such estimates as I have data for as soon as I have reduced the levels taken during my survey. I have sketched the whole on the accompanying map, and to give some further idea of the magnitude of the works, I add, in enumerating them, a rough calculation of their cost formed by comparing the works with Colonel Cautley's estimate, and the circumstances detailed in the foregoing report. In estimating for the canals I have taken the cost of larger channels of Ganges Canal than are required in Shahabad, to make up for the extra excavation consequent on a greater declivity.

1.—*Western Soane Canal.*

Anicut or dam at Bandoo, 6,000 running feet, at Rs. 120	Rs.	7,20,000
Deduct half chargeable to Eastern or Behar Canal	"	3,60,000
	Rs.	3,60,000
Head works at Bandoo	"	50,000
Twenty-two miles main channel on scale of 3rd Division Ganges Canal, or at 12½ lakhs for 70 miles	"	3,92,000
Remainder calculated at six branches of 40 miles each on scale of 6th Division Ganges Canal, or at 70 miles for 6 lakhs	"	20,58,000
Aqueducts, Hoosenee	"	1,00,000
Tootla	"	50,000
Kao	"	30,000
Banas	"	50,000
Total	Rs.	30,90,000
Add for land as per following paragraph	...	50,000
Grand Total	Rs.	31,40,000

being irrigation for a space of 2,037 square miles at Rs. 1,541 per mile.

* [I have since ascertained by comparison with the Railway levels that the Soane low water at Dehree is about 355 feet above the level of the sea. 1861.]

2.—*Tootla Reservoirs and Channels.*

Reservoir room for 6 square miles of drainage at 40 millions cubic feet per mile, or 240 millions, at Rs. 80	Rs.	19,200
Add for land	"	1,000
Six miles of channels at Rs. 1,000	"	6,000
Add for land	"	100
Total Rs. ...		26,300

being irrigation for 6 miles at Rs. 4,383 per square mile.

3.—*Dhooa Koond Reservoirs and Channels.*

Reservoir room for drainage of 24 square miles at 40 millions cubic feet per mile, or 960 millions cubic feet, at Rs. 60	Rs.	57,600
Add for land	"	2,900
Channels, 15 miles, at Rs. 2,000	"	30,000
Add for land	"	500
Total Rs.		91,000

being irrigation for 25 square miles at Rs. 3,640 per square mile.

4.—*Doorgowtee Reservoirs and Channels.*

Reservoir room for 276 miles of drainage at 40 millions cubic feet per mile, or 11,040 millions cubic feet at Rs. 60	Rs.	6,62,400
Add for land	"	33,000
Two channels of 35 miles each at Rs. 7,000 per mile	"	4,90,000
One ditto 6 miles at Rs. 3,000	"	18,000
Add for land	"	8,500
Total Rs		12,11,900

being irrigation for 287 square miles at Rs. 4,222 per mile.

5.—*Kora and Soora Reservoirs and Channels.*

Reservoir room for drainage of 198 square miles at 40 millions cubic feet each, or 7,920 millions cubic feet, at Rs. 60	Rs.	4,75,200
Add for land	"	23,800
Four channels of 10 miles each, at Rs. 3,000 ...	"	1,20,000
Add for land	"	2,000
Total Rs. ...		6,21,000

being irrigation for 204 square miles at Rs. 3,044 per mile.

6.—*Navigable Canal from Sasseram to Benares*—Of which I cannot at present give a rough Estimate.

53. In calculating the value of the land I have been guided by the Valuation Statement of land occupied for the Grand Trunk Road in Shahabad, which I procured from the Office of the Board of Revenue. I extract the following rates, which, however, appear to be extremely low:—

Kinds of Land.	Estimated gross value of annual produce or capability.	Ditto less half for Government Land Tax.	Deduct 10 per cent. as village expenses.	Balance net annual return.	Price at 20 years' purchase.
	Per Beegah in Indian Currency.				
	Rs. A. P.				Rs. A. P.
Cultivated, 1st sort ...	1 8 0	0 12 0	0 1 2·4	0 10 9·6	13 8 0
" 2nd " ...	1 0 0	0 8 0	0 0 9·6	0 7 2·4	8 15 0
" 3rd " ...	0 12 0	0 6 0	0 0 7·2	0 5 4·8	6 12 0
Fallow, recent, 1st sort.	0 8 0	0 4 0	0 0 4·8	0 3 7·2	4 8 0
" " 2nd "	0 6 0	0 3 0	0 0 3·6	0 2 8·4	3 6 0
" old 1st sort ...	0 4 0	0 2 0	0 0 2·4	0 1 9·6	2 4 0
" " 2nd " ...	0 3 0	0 1 6	0 0 1·8	0 1 4·2	1 11 0
Jungle nullahs, pits, &c.	0 2 0	0 1 0	0 0 1·2	0 0 10·8	1 2 0
	Per Acre in English Currency.				
	£ s. d.				£ s. d.
Cultivated, superior ...	0 4 9 ½	0 2 4¾	0 0 2·9	0 2 1·9	2 3 2½
" ordinary ...	0 3 2·2	0 1 8·1	0 0 1·9	0 1 6·2	1 8 7¼
" inferior ...	0 2 4·8	0 1 2·4	0 0 1·4	0 1 1	1 1 8
Fallow, recent, ordinary.	0 1 7·1	0 0 9·5	0 0 0·9	0 0 8·6	0 14 4
" " inferior...	0 1 2·4	0 0 7·2	0 0 0·7	0 3 6·5	0 10 10
" old, ordinary ...	0 0 9·6	0 0 4·8	0 0 0·5	0 0 4·3	0 7 0
" " inferior ...	0 0 7·2	0 0 3·6	0 0 0·3	0 0 3·3	0 5 6
Jungle nullahs, pits ...	0 0 4·8	0 0 2·4	0 0 0·2	0 0 2·2	0 3 7
	On the whole 1,105-4-15 Beegahs=690-3-31 acres, which included some Maafee or untaxed land.				
Indian Currency ... Rs.	401 8 3½	204 13 0½	20 7 9	184 5 3¼	3,686 9 10
English Currency ... £	40 3 1	20 9 7½	2 0 11$\frac{3}{7}$	18 8 8	368 13 2¾
		Average rate { Per Beegah		... Rs.	3 5 4
		{ Acre...		... £	0 10 8

The value of the land through which the canals will pass in the plains of Shahabad I estimate, according to the foregoing scale, to be about Rs. 6 per beegah (or £0-19-2½ per acre). The value of the hill country to be occupied for reservoirs will not exceed Rs. 1-8-0 per beegah (£0-4-9½ per acre).

For the Soane Canal will be required as follows :—

22 miles main channel 300 feet, width of land $\frac{22 \times 1760 \times 100}{3025}$ =1,280 beegahs.

6 Branches of 40 miles each 150 feet, width of land $\frac{6 \times 49 \times 1760 \times 50}{3025}$ =6,982 beegahs.

In all 8,262 beegahs at Rs. 6=Rs. 49,572.

Or 5,164 acres £0-19-2½, £4,957.

For the Doorgowtee Reservoirs I suppose the area of land to be occupied will not exceed 20 square miles, almost all now jungle: that is, the price will be—

20,480 beegahs at Rs. 1-8...	...	Rs. 30,720
or 12,800 acres, at £ 0-4-9½	...	£ 3,072

The others I calculate in proportion, that is, about 5 per cent. on the reservoirs, and 1⅔rd per cent. on the canals and channels.

54. In estimating the returns from these works, I shall compare them with the anticipated return on the Great Ganges Canal according to Lieutenant Colonel Smith's last calculation. The revenue from sources exclusive of water rent has been assumed by Lieutenant Colonel Smith at $\frac{1}{6}$th of the latter; but as my rate of water rent is higher, I shall assume $\frac{1}{10}$th of it for the probable returns from other sources on the Shahabad Canals.

	Ganges Canal.	Soane Canal.	Reservoir irrigation.
	Rs.	Rs.	Rs.
Cost per square mile of country to be irrigated.	2,415*	1,541	4,000
Gross returns on water rent if working in full... } Per square mile	197†	427	427
Ditto on other items	33	43	43
Total gross returns, work at full rate	230	70	70
Being per cent. on outlay	9½	30	11¾
Deduct charges assumed as Col. Smith does ...	2½	2½	2½
Net return per cent. in full work	7	28	9¼
Working ⅔rd of full rate, the gross return is ...	6⅓	20	8
Deduct charges	2½	2½	2½
Net return when working at ⅔rd of full rate per cent.	3⅚	17½	5½

* Total 1,63,00,000—6,750 cubic feet per second of water irrigating 211 acres each, or distributed over three times this area 1 square mile nearly, $\frac{1,63,00,000}{6750}$=2,415.

† $\frac{13,27,500}{6750}$=197 nearly.

The average cost of the whole irrigation of Shahabad, will thus be about Rs. 2,200 (£220) per square mile, yielding about 19 per cent. net return when in full work, and 11¾ per cent. when working at ⅔rds of the full rate. We may, therefore, be able to afford some reduction of the water rent above proposed. But this is a matter for future discussion.

55. The total cost of the irrigation works for Shahabad on the foregoing rough estimates will be about 61 lakhs of Rupees (£610,000). The total annual payments to be required of the cultivators will be 12⅘ lakhs (£128,000) when the irrigation is in full use, and 9⅙ lakhs (£91,500) when working at ⅔rds of the full rate. The total of the Land Tax of Shahabad is Rs. 13,94,396 (£139,440), as stated in the printed Statistical Return.

The irrigation in full work will cover 960,000 beegahs (600,000 acres) of land, and will, I suppose, on the average increase the produce of wheat and barley at least 2½ maunds per beegah, or 320 lbs. (⅐th of a ton) per acre. The price of the produce in Shahabad is about 50 seers (100 lbs.) of wheat, and 70 seers (140 lbs.) of barley for the Rupee (2 shillings). Supposing the quantities equal, the average price will be 60 seers for the Rupee, or £1-16-0 per ton, whence Rs. 1-10-8 is the value of the increased produce per beegah; and £0-5-2½ per acre. This may, I think, safely be taken as the increased value of the spring crops consequent on the introduction of canal irrigation, and for the whole 960,000 beegahs (600,000 acres) it makes the increase Rs. 15,42,858 (£154,286), so that the increase of grain in the spring crop alone on ⅓rd the area of the district will pay the water rent, leaving the saving in labour on the spring crop and the use of the canal for the remainder of the year clear gain to the cultivators.

56. Having given such a detail of these works as I am at present able to present, I beg to submit for the consideration of the Lieutenant Governor the method I would suggest as the most advantageous for carrying them out. I think it very undesirable that the whole should be put in hand at once, even if it were possible.

1st. Because there would be great difficulty in getting Engineers and Subordinate Establishment.

2nd. Because if got together they would all want the local experience which is so advantageous in carrying on work cheaply and efficiently.

3rd. Because I think it highly desirable to unite the execution of these works with the development of the resources of the district, in workmen, in iron, coal, &c., which we must in a great measure procure from extraneous sources, if the work be carried on rapidly; whereas if we begin by establishing workshops on the small scale, smelting our own iron, and teaching our own Mechanics and Sub-Engineers, we shall soon raise an indigenous staff, be inde-

pendent of foreign support, and we shall set agoing various trades and manufactures in the District.

4th. Because the agricultural habits and prejudices of the Natives must be overcome, which will be best done by the gradual introduction of the new modes of irrigation; otherwise our finished works may stand useless in part and unprofitable, while the people are learning slowly the benefit to be derived from them.

5th. Because small works will be sooner completed than large, and therefore portion of the benefits to be derived from extended irrigation, and the returns on the expense, will be more quickly realized.

57. I have stated (para. 8) that the River Kao is dammed across in 14 places, which dams retain water for the rice, but not for the spring crops. I would begin the irrigation works by carrying a small canal from the Soane at Bandoo to the Kao near where it crosses the Grand Trunk Road. This canal should be so constructed that it may be afterwards enlarged to form the main trunk of the Soane Canal; but at first it should only be used to fill the Kao Reservoirs, and perhaps to afford a few irrigation channels above its junction with the Kao. The dam at Bandoo I would make a very temporary structure of piles, earth, and mats; and I would cross both the Hoosenee and Tootla on temporary earthen aqueducts. I suppose the Zemindars would be glad to pay a moderate sum for filling the reservoirs, and I beg permission to address the Collector of Arrah on the subject.

58. This temporary canal and one reservoir at the Dhooa Koond, and another at the Tootla, are all the irrigation works that I would recommend for immediate sanction.

59. But it will be very desirable for the rapid and convenient construction of the proposed short canal to have a road from Bandoo Ghat to the Grand Trunk Road practicable at all seasons. The present road is a very good fair-weather track, and partially bridged from Dehree (viâ Tilothoo) to Akberpoor, and a made road exists from Sasseram to Tilothoo. From Akberpoor to Bandoo (7 miles) the road, though practicable for carts, is a very indifferent track and quite unbridged.

60. The construction of a line of road from Bandoo to Sasseram or Dehree, or some intermediate point on the Grand Trunk Road, is connected with the project for irrigation in another way. For with reference to what I stated in paragraph 32 concerning the Dhooa Koond Reservoirs, the adoption of a line joining the Grand Trunk Road between Sasseram and Dehree would perhaps enable us to dispense with the Sasseram and Tilothoo Road, and occupy the large site for reservoirs spoken of in the paragraph quoted.

61. Unconnected with the irrigation project, a road from Sasseram to Bandoo is very important for the general traffic of the country, and specially for the Palamow coal. Bandoo is about 40 miles from the Coal Field; and the addition of 40 miles of road to the line above referred to would give the means of bringing this

coal into the markets on the Ganges. It has, I believe, been proposed to make a road from Palamow to Sherghotty, and thence to carry the coal by the Patna and Gya Road to the former city.

But I would suggest that the line of road from Palamow to the Grand Trunk Road near Sasseram is preferable for the following reasons—unless, indeed, the difficulties of the country between Palamow and the mouth of the Koel shall be found very great:—

1st. The Palamow coal is more likely to be required up than down the line of the Ganges, because the Lower Provinces may be supplied from the Damoodah and Kurhurbalee Fields.

2nd. There is a great demand for coal for the Soane bridge and other Railway works in Shahabad, and the line of road from Palamow to the Soane opposite Bandoo will secure the navigation of the Soane to such extent as it may be found practicable or advantageous to use it.

3rd. We may soon be able to afford water carriage from Bandoo to Sasseram, and eventually to Arrah. Hence the road from Palamow to the Soane at the juncture of the Koel has a great advantage over the Sherghotty Line.

4th. The construction of the line of road from Palamow to near Sasseram could very conveniently be undertaken by the Executive Engineer entrusted with the irrigation works mentioned in the 56th and 57th paragraphs, as the whole will lie in a small compass. This is a practical advantage of no small importance while the difficulty of finding Engineers continues to be so great.

62. While on the subject of the transport of the Palamow coal, I beg to draw attention to the possibility of rendering the Koel River navigable. I have not seen the river myself except just at the mouth. But on a sketch map of the Palamow District, of which Mr. Campbell, the Agent of the Bengal Coal Company, obligingly allowed me to take a copy, I find it noted that the navigation of the Koel is impeded by a mass of rocks at Sicksicky, which might be removed by blasting. To remove these rocks would, I apprehend, cause a change in the declivity of the river unfavourable to navigation, but it is very possible that they may be avoided by cutting a channel with locks so as to pass round the obstacle and overcome the difference of level above and below it without drawing too heavily on the discharge of the river.

63. I have only now to add that it seems that the Soane affords abundance of water for the irrigation of a large portion of the Behar and Patna Districts in addition to Shahabad, while in the former districts I understand the want of water is even more urgent than in the latter.

64. In requesting orders on the proposed mode of carrying out the irrigation works (paragraphs 55 to 57), and with reference to the means of communication discussed in paragraphs 58 to 61, I beg most strongly to recommend that an examination of the country on the right bank of the Soane be undertaken next cold season, with the view to constructing canals for irrigation.

65. I venture to express a hope that I may be favoured with the Lieutenant Governor's orders on this report as early as possible, in order that I may frame my estimates accordingly, and make the necessary arrangements and applications for Executive and Surveying Establishments, and for instruments, to carry out such measures as His Honour may be pleased to sanction.

I have, &c.,

C. H. DICKENS, *Captain.*

PUBLIC WORKS DEPARTMENT.

REVENUE.

No. 11 *of* 1856.

OUR GOVERNOR GENERAL OF INDIA IN COUNCIL.

WITH your letter in this Department dated the 19th October (No. 9) 1855, you submit for our favorable consideration a plan by Captain C. H. Dickens of the Bengal Artillery, for the irrigation of the Districts of Shahabad and Behar.

2. You state that you attach "the highest importance to the various objects proposed by Captain Dickens" and placing "great reliance on the accuracy and sufficiency of the data on which his project is founded, and in full confidence that the result of this important measure will be peculiarly remunerative, and in every point of view beneficial to the state" you solicit us to give such a general sanction to the undertaking as shall enable you, on the submission of complete estimates for any portion of the work, to authorize its immediate execution.

3. The total cost of the work is roughly estimated by Captain Dickens at sixty-one lacs of Rupees, or, adding the half cost of the dam at Bandoo which is excluded as chargeable to a canal to be hereafter made of the Soane for the purpose of irrigating Behar, to nearly sixty-five lacs. Lieutenant Colonel Baker has examined the estimates and, with the exception of the Soane dam which he thinks will cost more than is supposed, he thinks that they "give as fair an approximation and can now be obtained to the probable cost of the works."

4. We have carefully considered the whole project, we doubt not that an improved system of irrigation would greatly benefit the districts alluded to, and we think it probable that the undertaking might yield an adequate pecuniary return, but we would remind you that the Provinces of Behar and Benares are the most favored of any portion of India in their exemption from the calamities of drought on the one hand, and of excessive inundation on the other, and we think therefore that other parts of our Territories claim your attention for works of this character more urgently than the Behar Districts. The subject however is one

which can only be considered in the Annual Budget of Public Works for India and with respect to the existing state of our finances. In the meantime the preparation of detailed Surveys and Estimates may be proceeded with, so that no time may be lost when the fitting opportunity shall arrive for conveying to you the authority which you solicit.

5. We desire that you will communicate to Captain Dickens through the proper channel, the high sense which we entertain of his services, and we fully concur in the opinion recorded by you that he is "deserving of the highest praise for the great care and ability with which he has conducted the enquiry up to the present point, for the great amount of field work done, and of valuable local information obtained in so short a time, and with such very little assistance, and for the clear and concise manner in which he has laid before Government the result of his labours."

We are, &c.,

LONDON, 11*th June* 1856. (Sd.) W. H. SYKES AND OTHER DIRECTORS.

Extracts containing estimates of the quantities and cost of water raised by the Native methods and required for irrigation of the crops.

The following Table is extracted from the *Calcutta Gleanings in Science*, Vol. I. (1830), page 205.

"A Table showing the performance and its cost, in raising water from 10 to 25 feet by different methods of employing animal power. The expense of each labourer is put at 2 annas (3 pence) per diem, except in the instance of the walking beam, just half as much more on account of wear and tear of machine.

No.	Height raised in feet.	No. of persons equivalent.	Method.	Stages.	Loads per hour.	Cubic Feet. Per load.	Cubic Feet. Per hour.	Hours labour.	Total performance in the period. Cubic feet.	Total performance in the period. Hogsheads.	Hogsheads per man.	Hogshead per Rupee.	Period of labour.
1	10	5	Baling* ...	2	1,200	0·33	400	6	2,400	300	60	480	Whole day.
2	11	3	Bullocks ...	1	44	1·75	77	6	462	57·75	19·5	312	Half day.
3	11	1	Walking beam	1	800	0·50	400	8	3,200	400	400	2,250	Whole day.
1	45	50	Baling ...	10	1,200	0·33	400	6	2,400	300	6	48	Whole day.
2	45	5	Bullocks ...	1	32	1·75	56	12	672	84	16·8	135	Whole day.
3	45	6	Walking beam	4	800	0·50	400	12	4,800	600	100	533	Whole day.
4	45	100	Baling ...	10	1000	0·33	332	12	3,948	498	5	40	Whole day.

* "Tossing water by means of basket ladles or scoops held by ropes, from one level to another."

GLEANINGS IN SCIENCE (CALCUTTA 1830), VOLUME II., PAGE 29.—"A *latha* from a well which is 36 feet to the water from surface, in half an hour drew 1,357 lbs. of water; two men usually work from sun-rise to 9 o'clock, and from 3 o'clock to sun-set, or rather until dark. When the depth is moderate 3 men with 2 lathas' water from about ⅔rds of an acre to ⅓rd, daily.

"Three men and two oxen work a *moth* from morning until evening, with a refreshment only of about ¾ths of an hour. In a well 33 feet from the surface to the water, a *moth* in half an hour drew 7,210 lbs; but such superiority over the *lathas* is not admitted by the natives, who contend that three *lathas* wrought by four men are equal to a *moth* wrought by three men and two oxen. This, however, I have no doubt is a mistake, unless when the water is very near the surface."

Table extracted from Madras Engineer Papers, Vol. II. (1846.)

Method of Baling.	Height raised in feet.	No. of men or Bullocks employed. Men.	No. of men or Bullocks employed. Bullocks.	Lifts per hour.	Cubic Feet. Per lift.	Cubic Feet. Per hour.	No. of hours labour.	Total performance in the time.	Effect of Labour. Raised 1 foot high per minute.	Effect of Labour. Raised 1 foot high per day.	Effect of Labour. Delivery per Rupee raised 1 foot high.
								c. f.	c. f.	c. f.	c. f.
1 Pecottah [or *Lât*] ...	10	2	0	600	⅚	500	6	3000	83·33	30000	96000
2 Do	20¼	2	0	300	1·44	432	6	2592	145 8	52488	1586304
3 Do	20¼	2	0	240	1·6	384	6	2304	129·6	46656	115704
4 Basket scoops	10	6	0	1320	⅓	440	6	2640	73·33	26400	28160
5 Common Bullock Cuppilay [or *Moth.*] ...	11	0	1	44	1·75	77	12	924	14·116	10163·52	54208
6 Do	20	0	1	90	2	180	6	1080	60·	21600	115200
7 Do	45	0	1	32	1·75	56	12	672	42·	30240	161280
8 Retta Cuppilay in Horticultural Garden ...	15	0	1	180	1·32	237·6	8	1900·8	59·4	28512	152004
9 Common Pump	10	1	0	60	per min. 8	480	8	3840	80·	38400	122880

N. B.—This table is the result of experience gained in unwatering the foundation of a bastion of Fort St. George.

From the Calcutta Engineer's Journal, March 1861, *page* 33.

"The second source of supply, *viz.* wells, is the one solely used this year for land situated above 6 miles from the canals; but from the failure of the rain crop, and the consequent scarcity of cattle forage, this method can only be adopted to a very limited extent, as the immense area of uncultivated land in the Doab at present shows.

"The area of wheat land that can be irrigated by two pairs of bullocks working one leathern bag is about 4 acres, of barley 8 acres.

"The practice of watering is as follows:—

"A whole ox hide, formed into a bag, is suspended at the end of a stout rope, which is carried over a wheel fixed about 8 feet above the well's mouth. When the bag is filled, the other end of the rope is attached by a loop and peg to the yoke of one pair of bullocks, which are then driven down the slope from the well's mouth. When the bullocks reach the foot of the slope, the bag has arrived at the surface of the ground, where it is emptied by the attendant. In the meantime the second pair of bullocks has arrived at the top of the slope where the wheel is fixed, in order

to be ready for the next lift. These two pairs of bullocks require the attendance of three men.

"One driver, one to fill and empty the bag, and the third, who under any system of Irrigation would be required, to guide the water into the proper channels.

"From personal measurement we deduce that a leather bag as used in the North-West Provinces contains 4·5 (four and a half,) cubic feet, and that two pair of bullocks, relieving each other in the manner above described, will raise this bag full of water to the surface of the ground forty times in an hour. Supposing the bullocks work ten hours a day, and taking ninety days as the working season, we have the following result:—$4·5 \times 40 \times 10 \times 90 = 162{,}000$ cubic feet. One acre $=43{,}560$ superficial feet. $\frac{162000}{43560} = 3·72$ acres, covered 1 foot deep with water, as the result of the labour of two pairs of bullocks and three men, working ten hours a day for ninety days. The difference between these figures and the previous statement that water, equivalent to a rainfall of 15 inches, is necessary for the wheat crop, is accounted for by the usual Christmas rains, which even this year have not failed us. From the above description of the well system of Irrigation, it will be seen that it is very expensive, and can only be of very restricted application.

"Beside the objection of expense in working, this system is quite impracticable in large tracts of the Doab, as the sandy nature of the sub-soil entails the necessity of masonry wells, and it is quite plain that such a well, costing at least Rs. 500 to even every 20 acres, is entirely out of the question. The ordinary well is simply a round hole, lined, for a few feet of its height from the bottom, with a wooden, or plaited brush-wood casing."

APPENDIX B.

DETAILED ESTIMATES ON WHICH THE PROJECT OF 1861 IS BASED.

NO. 1, EXCAVATION OF CHANNEL.

Part I.—Western Soane Canal.

Names of Branches.	No. of Miles.	Depths. Greatest.	Depths. Least.	Depths. Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
A. Western Canal Main Line ...	Lock Channel.	21·1	3·1	17·3	73	12,130,010	
	1	22·3	2·0	15·8	73	9,097,777	
	2	36·0	19·3	28·9	...	21,892,670	
	3	32·3	20·2	25·7	...	18,263,110	
	4	24·0	16·3	21·5	...	13,895,400	
	5	26·0	17·6	20·6	...	13,029,535	
	6	21·2	18·1	19·7	...	12,256,345	
	7	20·5	12·4	17·6	...	10,380,715	
	8	13·5	10·3	12·3	...	6,325,635	
							117,271,197
	9	11·4	6·9	9·3	...	4,280,669	
	10	8·7	4·6	6·7	...	2,960,610	
	10·33	6·6	5·6	5·9	...	720,675	
	Escape Channel 5 Miles.			10	73	207,907,000	
							30,796,920

ABSTRACT.

	Rs.
117,271,197 Cubic feet of excavation at Rs. 4 per 1,000 feet in first 8 miles...	4,69,085
30,796,920 Cubic feet of excavation at Rs. 2-8 per 1,000 feet in remainder	76,992
Contingencies at 5 per cent.	27,304
Total Co.'s Rs ...	5,73,381

Names of Branches.	No. of Miles.	Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
B. Arrah Branch above Ranee-sagor branch Head.	[illegible]/11th of 11th	13·8	4·4	9·1	42·5	2,024,900	
	12th	13·[illegible]	6·0	11·1	...	3,624,110	
	13th	14·4	6·0	10·7	...	3,363,890	
	14th	16·3	6.7	10·5	...	3,495,015	
	15th	13·3	9.4	11·1	...	3,431,035	
	16th	10·0	5·7	8·7	...	2,306,520	
	17th	12·8	4.7	8·7	...	2,363,965	
	18th	13·0	10·9	11·8	...	3,789,830	
	19th	13·2	8·2	11·9	...	3,421,910	
	20th	9·4	5·7	7·3	...	2,083,120	
	21st	13·9	5·0	9·0	...	2,999,820	
	22nd	12·1	4·4	10·6	...	3,277,035	
	23rd	11·8	6·7	7·9	...	2,329,565	
	24th	9·6	5·5	7·4	...	2,125,520	
	25th	7·0	4·4	6·4	...	1,730,070	
	26th	9·1	3·6	7·3	...	2,066,740	
Carried over	......	...	...	...	...	44,433,045	148,068,117

Names of Branches.	No. of Miles.	Depths. Greatest.	Depths. Least.	Depths. Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
Brought forward	......	...	...	...	...	44,433,045	148,068,117
	27th	9·7	6·8	8·6	42·5	2,528,245	
	28th	12·5	9·1	10·4	...	3,241,730	
	29th	13·3	5·5	8·3	...	2,414,215	
	30th	13·1	10·6	11·4	...	3,611,545	
	31st	10·8	4·7	8·0	...	2,280,720	
	32nd	11·2	5·0	8·0	...	2,318,880	
	33rd	14·6	6·8	12·3	...	1,342,115	
	Escape Channel 1½ miles to Soane...			10·0	...	4,554,000	66,724,495

ABSTRACT. Rs.

66,724,495	Cubic feet of excavation at Rs. 2-8 per 1,000 feet	1,66,811
	Contingencies at 5 per cent.	8,340
	Total Co.'s Rs. ...	1,75,151

Names of Branches.	No. of Miles.	Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
C. Arrah Branch above Peeroo Branch Head.	·67 of 33rd	12·4	9·9	10·8	31	1,858,800	
	34th	12·6	7·7	9·6	...	2,282,560	
	35th	8·2	5·8	7·3	...	1,636,405	
	36th	6·3	3·7	5·4	...	1,138,195	
	37th	11·7	4·1	8·9	...	1,925,800	
	38th	12·9	6·8	9·8	...	2,388,620	
	39th	11·0	4·1	7·9	...	1,813,745	
	40th	5·2	1·2	3·2	...	621,200	
	·28 of 41st	7·4	3·6	4·7	...	274,140	
	Escape Channel 4 Miles to Bunas.			10·0	31	9,715,200	23,654,665

ABSTRACT. Rs.

23,654,665	Cubic feet of excavation at Rs. 2-8 per 1,000 cubic feet.	59,136
	Contingencies at 5 per cent.	2,957
	Total Co.'s Rs. ...	62,093

Names of Branches.	No. of Miles.	Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
D. Arrah Branch above Nansaugor Branch Head.	0·72 of 41st	7·9	6·2	6·8	23	887,855	
	42nd	7·9	4·5	6·4	...	1,125,605	
	43rd	7·5	2·4	5·4	...	894,045	
	44th	6·6	3·7	5·5	...	930,395	
	45th	6·5	4·9	5·8	...	993,650	
	46th	8·4	6·1	6·6	...	1,170,530	
Carried over	......	...	...	...	...	6,002,080	238,447,277

Names of Branches.	No. of Miles.	Depths. Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
Brought forward	......	...	...	...	...	6,002,080	238,447,277
	47th	8·9	4·9	7·2	...	1,343,345	
	48th	12·5	4·2	10·1	...	1,961,980	
	49th	9·8	7·5	8·5	...	1,628,975	
	50th	9·1	5·9	7·6	...	1,395,425	
	51st	11·8	3,5	7·9	...	1,439,015	
	52nd	11·2	7·4	10·1	...	2,032,960	
	53rd	9·0	3·2	6·2	...	1,066,125	
	54th	8·2	2·1	6·5	...	1,124,050	
	55th	6·9	3·5	5·4	...	899,060	
	56th	5·0	2·2	4·3	...	692,375	
	·25 of 57th	3·8	3·4	3.5	...	125,440	
	Escape Channe 2 miles to Soane.			10·0	23	4,012,800	23,723,630

ABSTRACT.

	Rs.
23,723,630 Cubic feet of excavation at Rs. 2-8 per 1,000 cubic feet.	59,312
Contingencies at 5 per cent.	2,965
Total Co.'s Rs. ...	63,277

Names of Branches.	No. of Miles.	Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
E.							
Arrah Branch to Terminus at Arrah.	·75 of 57th	5·8	3·3	4·9	18·5	5,33,085	
	58th	6·4	3·1	5·3	...	7,48,425	
	59th	7·9	2·4	4·8	...	6,74,225	
	60th	11·2	3·5	7·9	...	12,87,765	
	61st	6·1	3·6	5·2	...	7,24,410	
	62nd	4·0	2·8	3·3	...	4,19,555	
	63rd	8·4	2·4	6·2	...	9,14,825	
	64th	6·5	5·2	5·8	...	8,40,045	
	65th	7·4	3·0	5·2	...	7,44,005	
	66th	9·6	4·9	7·8	...	12,69,340	
	67th	10·8	9·1	10·0	...	17,90,130	
	68th	9·1	4·7	6·6	...	10,16,025	
	69th	6·2	3·2	3·3	...	4,15,225	
	70th	8·4	2·7	5·2	...	7,32,550	
	71st	4·7	4·1	4·3	...	5,77,300	
	72nd	7·2	4·4	5·3	...	7,72,675	
	73rd	6·1	3·2	4·6	...	6,21,605	
	74th	5·2	2·9	4·0	...	5,54,890	
	75th	6·1	1·9	4·0	...	5,31,675	
Carried over	...	...	...	...	...	15,167,755	262,170,907

Names of Branches.	No. of miles.	Depths. Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
Brought forward	......	...	...	...	...	15,167,755	262,170,907
	76th	7·0	3·0	5·2	...	7,30,815	
	77th	6·8	4·4	5·7	...	8,29,395	
	·7 of 78th	3·9	0·3	2·1	...	25,050	
							16,753,015

ABSTRACT.

		Rs.
16,753,015	Cubic feet of excavation at Rs. 2 per 1,000 cubic feet	33,506
	Contingencies at 5 per cent.	1,675
	Total Co.'s Rs. ...	35,181

Names of Branches.	No. of miles.	Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
F. Nansaugor Branch	1st	9·2	3·2	7·3	8	5,56,180	
	2nd	13·7	9·2	11·8	...	16,11,565	
	3rd	13·6	11·1	12·5	...	17,95,655	
	4th	11·1	5·3	8·8	...	9,96,110	
	5th	8·2	6·6	7·3	...	7,43,265	
	6th	7·1	5·4	6·2	...	5,76,905	
	7th	6·4	4·5	5·1	...	4,39,000	
	8th	7·9	6·2	7·0	...	7,04,070	
	9th	7·5	5·7	7·0	...	6,77,200	
	10th	9·6	3·6	5·8	...	5,08,380	
	11th	4·2	3·0	3·7	...	2,69,320	
	12th	5·6	2·1	4·3	...	3,44,460	
	13th	5·8	0·1	3·7	...	2,40,435	
	14th	3·6	0·3	1·5	...	81,625	
	15th	2·9	1·6	2·0	...	1,19,400	
	16th	9·9	2·9	6·2	...	5,80,640	
	17th	8·3	3·7	5·1	...	4,31,525	
	18th	5·1	2·3	4·0	...	302,605	
	19th	5·7	2·7	4·0	...	293,550	
	20th	13·0	2·8	6·3	...	724,920	
	21st	12·2	9·3	10·8	...	1,400,325	
	22nd	9·3	4·2	6·7	...	660,410	
	·41 of 23rd	6·0	0·6	3·7	...	106,600	
							14,164,145

ABSTRACT.

		Rs.
14,164,145	Cubic feet of excavation at Rs. 2 per 1,000 cubic feet	28,328
	Contingencies at 5 per cent.	1,416
	Total Co.'s Rs. ...	29,744

Carried over	293,088,067

Brought forward		293,088,067
G.		
Peeroo Branch above the Jugdispoor Branch Head, $11\frac{1}{2}$ miles, with 6 miles of escape to the Bunas, total $17\frac{1}{2}$ miles, 17 feet wide at bottom, average depth of cutting say 8 feet, slopes $1\frac{1}{2}$ to 1. Thus $17\frac{1}{2} \times 5280 \times 8 \times (17 + \frac{3}{2} + 8) =$ cubic feet	...	21,436,800
Cost.	Rs.	
21,436,800 Cubic feet at Rs. 2 per 1,000 cubic feet ...	42,874	
Contingencies at 5 per cent.	2,144	
Total cost Rs. ...	45,018	
H.		
Peeroo Branch below Jugdispoor Branch Head, $17\frac{1}{2}$ miles to tail escape in Nala, width at bottom 11 feet, average depth say 5 feet, slopes as before. Thus $17\frac{1}{2} \times 5280 \times 5 \times (11+5 + 2\frac{1}{2} =$ cubic feet	...	8,547,000
Cost.	Rs.	
8,547,00 Cubic feet at Rs. 2 per 1,000 cubic feet	17,094	
Contingencies at 5 per cent.	8,855	
Total cost Rs. ...	17,949	
I.		
Jugdispoor Branch, 17 miles to tail escape in Charyee, width at bottom $10\frac{1}{2}$ feet, average depth say 5 feet. Thus $17 \times 5280 \times 5 \times (10\frac{1}{2} + 5 + 2\frac{1}{2}) =$ cubic feet	...	8,078,400
Cost.	Rs.	
8,078,400 Cubic feet at Rs. 2 per 1,000 cubic feet	16,157	
Contingencies at 5 per cent.	808	
Total cost Rs. ...	16,965	
J.		
Raneepoor Branch above escape, 22 miles, with escape to Jhooree Nuddee 2 miles, total 24 miles, width at bottom 16 feet, average depth of cutting say 7 feet. Thus $24 \times 5280 \times 7 \times (16+7 + 3\frac{1}{2}) =$ cubic feet ...	...	23,506,560
Cost.	Rs.	
23,506,560 Cubic feet at Rs. 2 per 1,000 cubic feet	47,013	
Contingencies at 5 per cent.	2,350	
Total cost Rs....	49,363	
K.		
Raneepoor Branch below escape, $13\frac{1}{2}$ miles, including tail escape to Kao, width at bottom $12\frac{3}{4}$ feet, average depth say 5 feet. Thus $13\frac{1}{2} \times 5280 \times 5 + (12\frac{3}{4} + 5 + 2\frac{1}{2}) =$ cubic feet...	...	7,177,100
Cost.	Rs.	
7,177,100 Cubic feet at Rs. 2 per 1,000 cubic feet	14,354	
Contingencies at 5 per cent.	718	
Total cost Rs....	15,072	
Carried over		361,833,927

Names of Branches.	No. of Miles.	Depths. Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
Brought forward	...	...	...	...	...	...	361,833,927
L.							
Sasseram Branch.	·43 of 11th	18·0	5·7	12·2	49	3,420,056	
	12th	15·7	13·3	14·7	...	5,231,925	
	13th	18·1	12·5	14·9	...	5,650,367	
	14th	19·6	13·7	16·8	...	6,619,534	
	15th	17·8	11·0	14·8	...	5,587,309	
	16th	18·4	8·3	13·6	...	5,074,948	
	17th	13·6	3·8	10·7	...	3,714,945	
	·79 of 18th	9·1	6·1	8·8	...	2,349,459	
	Escape Channel 2,000 ft. to Kao,		...	8·0	...	1,067,840	38,716,383

ABSTRACT.

		Rs.
38,716,383	Cubic feet of excavation at Rs. 3 per 1,000 cubic feet	1,16,149
	Contingencies at 5 per cent.	5,807
	Total Co.'s Rs....	1,21,956

M.

Sasserm Branch below the trifurcation and above escape, 22 miles, with 1 mile escape to Kordon, total 23 miles, width at bottom 20 feet, depth of cutting say 8 feet. Thus—

$23 \times 5{,}280 \times 8 \times (20+8+4) =$ cubic feet... 30,288,640

	Cost.	Rs.
30,288,640	Cubic feet at Rs. 2 per 1,000	60,577
	Contingencies at 5 per cent.	3,029
	Total cost Rs....	63,606

N.

Sasseram Branch to end, 18½ miles, including tail escape into Gooreea River, width at bottom 10½ feet, average depth of cutting say 5 feet.

$18\frac{1}{2} \times 5{,}280 \times 5 \times (10\frac{1}{2} + 5 + 2\frac{1}{2}) =$ cubic feet 8,791,200

	Cost.	Rs.
8,791,200	Cubic feet at Rs. 2 per 1,000	17,582
	Contingencies at 5 per cent.	879
	Total Co.'s Rs....	18,461

Carried over 439,630,149

Brought forward 439,630,149

O.

Jugjewan Branch above escape, $17\frac{1}{2}$ miles, with 2 miles escape to Gooreea, total $19\frac{1}{2}$ miles, width at bottom 14 feet, average depth of cutting say 7 feet.

$19\frac{1}{2} \times 5{,}280 \times 7 \times (14+7+3\frac{1}{2})$ = cubic feet 17,657,640

	Cost.	Rs.
17,657,640	Cubic feet at Rs. 2 per 1,000	35,315
	Contingencies at 5 per cent.	1,765
	Total cost Rs....	37,080

P.

Juggeewun Branch below escape, 15 miles to tail escape in Dhurmoutee, width at bottom $9\frac{1}{2}$ feet, average depth say 5 feet.

$15 \times 5{,}280 \times 5 \times (9\frac{1}{2}+5+2\frac{1}{2})$ = ... 6,732,000

	Cost.	Rs.
6,732,000	Cubic feet at Rs. 2	13,464
	Contingencies at 5 per cent.	673
	Total cost Rs....	14,137

Q.

Buxar Branch above Chowsa Branch Head, 8 miles, with escape of 7 miles to Dhurmoutee, total 15 miles; width at bottom 37 feet, depth of cutting say on the average 9 feet

$15 \times 5{,}280 \times 9 \times (37+9+4\frac{1}{2})$ 35,996,400

	Cost.	Rs.
35,996,400	Cubic feet at Rs. 2-8	89,991
	Contingencies at 5 per cent.	4,499
	Total cost Rs....	94,490

R.

Buxar Branch below Chowsa, and above Buradhee Branch Head, 11 miles, with 4 miles escape to Kao, total 15 miles; width at bottom $18\frac{1}{2}$ miles, average depth of cutting say 8 feet.

$15 \times 5{,}280 \times 8 \times (18\frac{1}{2}+8+4)$ 19,324,800

	Cost.	Rs.
19,324,800	Cubic feet at Rs. 2 per 1,000	38,649
	Contingencies at 5 per cent.	1,932
	Total cost Rs....	40,581

S.

Buxar Branch between the Buradhee, and Doomraon Branch Heads, $11\frac{1}{2}$ miles, with escape to Thora Nuddee, $1\frac{1}{2}$ miles, total 13 miles; width at bottom $14\frac{1}{2}$ feet, average depth of cutting say 7 feet.

$13 \times 5{,}280 \times 7 \times (14\frac{1}{2}+7+3\frac{1}{2})$ = cubic feet 12,012,000

Carried over 531,343,989

	Brought forward		531,343,989
	Cost.	Rs.	
12,012,000	Cubic feet at Rs. 2 per 1,000	24,024	
	Contingencies at 5 per cent.	1,201	
	Total cost Rs. ...	25,225	

T.

	Buxar Branch to end, 18 miles to tail escape into Nala, 10½ feet wide at bottom, average depth of cutting say 5 feet.		
	$18 \times 5{,}280 \times 5 \times (10\frac{1}{2} + 5 + 2\frac{1}{2})$ = cubic feet		8,553,600
	Cost.	Rs.	
85,53,600	Cubic feet at Rs. 2 per 1,000	17,107	
	Contingencies at 5 per cent.	855	
	Total cost Rs. ...	17,962	

U.

	Doomraon Branch, 13 miles to tail escape in Kao; width at bottom 7 feet, depth of cutting say 4 feet on average.		
	$13 \times 5{,}280 \times 4 \times (7 + 4 + 2)$ = cubic feet		3,569,280
	Cost.	Rs.	
3,569,280	Cubic feet at Rs. 2 per 1,000	7,138	
	Contingencies at 5 per cent.	357	
	Total cost Rs. ...	7,495	

V.

	Buradhee Branch, 13 miles to tail escape in Nala; width at bottom 8¾ feet, average depth of cutting say 5 feet.		
	$13 \times 5280 \times 5 \times (8\frac{3}{4} + 5 + 2\frac{1}{2})$, = cubic feet		5,577,000
	Cost.	Rs.	
5,577,000	Cubic feet at Rs. 2 per 1,000	11,154	
	Contingencies at 5 per cent.	558	
	Total cost Rs....	11,712	

W.

	Chowsa Branch above the Kochus Branch Head, 6½ miles, with escape of 7 miles to Dhurmoutee, total 13½ miles; width at bottom 26 feet, depth of cutting say 8 feet on average.		
	$13\frac{1}{2} \times 5280 \times 8 \times (26 + 8 + 4)$ = cubic feet		21,669,120
	Cost.	Rs.	
21,669,120	Cubic feet at Rs. 2-8 per 1,000	54,148	
	Contingencies at 5 per cent.	2,707	
	Total cost Rs....	56,855	
	Carried over		570,512,989

Brought forward		570,512,989
X.		
Chowsa Branch below Kochus Branch Head to escape, $12\frac{1}{2}$ miles, with 2 miles of escape to Koochana Nuddee, total $14\frac{1}{2}$ miles; width at bottom 21 feet, depth of cutting say 7 feet on average.		
$14\frac{1}{2} \times 5280 \times 7 \times (21 + 7 + 3\frac{1}{2}) =$ cubic feet		16,881,480
Cost.	Rs.	
16,881480 Cubic feet at Rs. 2 per 1,000	33,763	
Contingencies at 5 per cent.	1,688	
Total cost Rs. ...	35,451	
Y.		
Chowsa Branch to end, 15 miles, to tail escape into Kurumnassa; width at bottom $18\frac{1}{2}$ feet, depth of cutting say 6 feet on average.		
$15 \times 5280 \times 6 \times (18\frac{1}{2} + 6 + 3) =$ cubic feet		13,068,000
Cost.	Rs.	
13,068,000 Cubic feet at Rs. 2 per 1,000	26,136	
Contingencies	1,307	
Tot. cost Rs. ...	27,443	
Z.		
Kochus Branch 13 miles, to tail escape into Dhurmoutee; width at bottom 8. feet, depth of cutting say 5 feet.		
$13 \times 5280 \times 5 \times (8\frac{3}{4} + 5 + 2\frac{1}{2}) =$ cubic feet		5,577,000
Cost.		
5,577,000 Cubic feet at Rs. 2 per 1,000	11,154	
Contingencies at 5 per cent.	558	
Total cost Rs. ...	11,712	
Grand Total cubic feet of Channel Excavation in Western Soane Canal ...		606,248,496

APPENDIX B.—DETAILED ESTIMATES OF 1861.

NO. 1, EXCAVATION OF CHANNEL.

Part II. Eastern Soane Canal.

Names of Branches.	No. of Miles.	Depths. Greatest.	Depths. Least.	Depths. Mean.	Width at bottom.	Contents of each mile.	Total of each Branch.
a. Eastern Canal, Main Line ...	Lock Channel.	30·3	11·3	23·1	52	7,405,404	
	1st	29·9	7·2	19·5	...	8,898,602	
	2nd	31·3	17·6	24·3	...	11,284,205	
	3rd	31·3	15·7	24·3	...	11,419,270	
	4th	33·6	12·3	24·4	...	11,497,155	
	5th	33·7	15·1	25·8	...	12,161,965	
	6th	26·1	11·1	18·7	...	7,974,580	
	7th	25·8	10·2	19·0	...	8,247,240	
	8th	25·2	2·1	13·7	...	5,125,350	
	9th	22·3	1·2	12·1	...	4,692,255	
	10th	22·7	11·4	19·7	...	8,563,090	
	11th	20·1	13·0	16·9	...	6,787,060	
	12th	14·1	7·2	10·9	...	3,963,040	
	Escape Channel 2,000 feet to Shekhpoora Nala, from 11½ mile of Canal.			10	52	1,340,000	106,359,216

ABSTRACT.

	Rs.
106,359,216 cubic feet of excavation at Rs. 4 per 1,000... ...	4,25,437
Contingencies at 5 per cent.	21,272
Total Co.'s Rs. ...	4,46,709

Names of Branches.	No. of Miles.	Depths. Greatest.	Depths. Least.	Depths. Mean.	Width at bottom.	Contents of each mile.	Total of each Branch.
b. Patna Branch above Jakhoura Branch Head.	13th	10·1	5·2	7·7	38·5	2,044,155	
	14th	14·1	10·1	12·2	...	3,687,390	
	15th	11·7	6·4	9·8	...	2,841,080	
	16th	8·7	5·9	7·4	..	1,942,095	
	17th	14·5	9·2	12·0	...	3,606,700	
	18th	10·8	8·6	9·3	..	2,581,815	
	19th	11·3	8·1	9·0	...	2,481,995	
	20th	9·6	5·7	7·4	...	1,992,395	
	Escape Channel 2,000 feet to Soane		...	10·0	38·5	1,070,000	22,047,625

ABSTRACT.

	Rs.
22,047,625 cubic feet of excavation at Rs. 2-8 per 1,000 ...	55,097
Contingencies at 5 per cent....	2,755
Total Co.'s Rs. ...	57,852

Carried over 128,406,841

Names of Branches.	No. of miles.	Depths. Greatest.	Least.	Mean.	Width at bottom.	Cubic feet for each Mile.	Total of each Branch.
Brought forward	......	...	...	...	...	...	128,406,841
c.							
Patna Branch between Jakhoura at Kojhassa Branch Heads.	21st	8·8	5·5	7·0	34·5	1,685,615	
	22nd	5·5	3·4	4·5	...	987,120	
	23rd	5·3	1·9	4·5	...	1,002,650	
	24th	6·0	3·4	4·6	...	1,010,540	
	25th	12·1	1·2	5·6	...	1,385,715	
	26th	10·4	6·7	8·4	...	2,092,955	
	27th	12·6	4·8	7·4	...	1,809,605	
	28th	11·4	6·6	8·6	...	2,168,675	
	29th	7·3	2·6	5·2	...	1,170,475	
	30th	6·0	1·4	3·9	...	844,375	
	31st	13·5	1·7	10·1	...	2,710,855	
	32nd	10·1	3·9	7·3	...	1,775,225	
	33rd	9·4	2·8	5·6	...	1,337,665	
	34th	11·8	0·8	3·9	...	834,380	
	Escape Channel 3,000 feet to Soane.		..	10·0	34·5	1,485,000	22,330,850

ABSTRACT.

	Rs.
22,330,850 cubic feet of excavation at Rs. 2-8 per 1,000 ...	55,827
Contingencies at 5 per cent.	2,791
Total Co.'s Rs. ...	58,618

Names of Branches.	No. of miles.	Greatest.	Least.	Mean.	Width at bottom.	Cubic feet for each Mile.	Total of each Branch.
d.							
Patna Branch below Kojhassa and above Paleegunj Branch Heads.	35th	12·8	5·7	8·9	29·5	2,042,105	
	36th	11·4	5·3	8·7	...	1,833,610	
	37th	6·7	3·3	4·8	...	954,485	
	38th	8·1	6·0	6·8	...	1,459,940	
	39th	8·6	4·2	7·1	...	1,521,980	
	40th	11·1	4·5	8·0	...	1,776,665	
	41st	11·9	2·2	6·1	...	1,323,795	
	42nd	11·4	3·0	5·3	...	1,019,500	
	43rd	12·4	2·7	7·5	...	1,634,805	
	44th	5·9	4·3	5·0	...	983,375	
	45th	11·1	3·2	6·6	...	1,365,160	
	46th	7·9	4·7	6·5	...	1,307,870	
	47th	8·3	4·1	5·4	...	1,087,535	
	48th	4·5	2·6	3·7	...	707,895	
	49th	10·6	4·1	8·5	...	1,897,790	
	50th	10·3	5·5	8·1	...	1,779,760	
	51st	9·4	5·3	7·4	...	1,609,865	
	52nd	8·3	3·9	5·9	...	1,204,095	
	53rd	6·0	3·1	3·3	...	629,370	
	54th	5·6	3·8	4·5	...	888,870	
Carried over	......	...	...	...	...	28,363,470	150,737,691

Names of Branches.	No. of Miles.	Depths. Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
Brought forward	......	...	..	...	...	28,363,470	150,737,691
	55th	6·3	5·0	5·6	...	1,118,155	
	56th	11·7	5·0	10·1	...	2,385,555	
	57th	9·0	5·3	6·9	...	1,450,015	
	58th	5·9	4·0	5·3	...	1,063,455	
	59th	5·5	3·1	4·5	...	862,005	
	60th	4·9	0·0	4·0		787,045	
	·62 of 61st	7·8	1·1	4·1		485,590	
	Escape Channel 3,000 feet to Soane		...	10·0	29·5	1,335,000	
							36,515,290

ABSTRACT.

	Rs.
36,515,290 cubic feet of excavation at Rs. 2-8 per 1,000 ...	91,288
Contingencies at 5 per cent.	4,564
Total Co.'s Rs. ...	95,851

Names of Branches.	No. of Miles.	Greatest.	Least.	Mean.	Width at bottom.	Cubic feet in each Mile.	Total of each Branch.
e. Patna Branch below Paleegunj and above Dinapoor Branch Heads.	·38 of 61st	5·4	3·3	4·0	26	276,735	
	62nd	5·7	3·5	4·7	...	842,585	
	63rd	10·1	4·0	7·7	...	1,602,180	
	64th	9·6	7·3	8·7	...	1,803,080	
	65th	7·6	5·4	6·5	...	1,235,005	
	66th	6·5	2·1	4·7	...	814,505	
	67th	5·5	2·1	3·5	...	593,855	
	68th	9·0	3·8	7·0	...	1,365,075	
	69th	4·9	0·9	3·6	...	608,750	
	70th	4·1	0·7	3·3	...	565,375	
	·45 of 71st	5·3	1·3	2·1	...	225,815	
	Escape Channel 4,000 feet to Soane		...	8·0	26	1,216,000	
							11,148,960

ABSTRACT.

	Rs.
11,148,960 cubic feet of excavation at Rs. 2-8 per 1,000	27,872
Contingencies at 5 per cent. ...	1,394
Total Co.'s Rs. ...	29,266

f.

Patna Branch from Dinapoor Branch Head to terminus in Ganges, 27 miles; width at bottom 18 feet, depth of cutting, say 7 feet on the average.

$27 \times 5280 \times 7 \times (18+7+3\frac{1}{2})$ = cubic feet 28,440,720

Carried over 226,842,661

Brought forward		226,842,661
Cost.	Rs.	
28,440,720 cubic feet at Rs. 2-8 per 1,000	71,102	
Contingencies at 5 per cent.	3,555	
Total cost Rs....	74,657	

g.

Jakhoura Branch to tail escape in Poonpoon, $24\frac{1}{2}$ miles; width at bottom 9 feet, depth of cutting say 5 feet on an average.		
$24\frac{1}{2} \times 5280 \times 5 \times (9+5+2\frac{1}{2})$ = cubic feet	...	10,672,200
Cost.	Rs.	
10,672,200 cubic feet at Rs. 2 per 1,000	21,344	
Contingencies at 5 per cent.	1,067	
Total cost Rs....	22,411	

h.

Kojhassa Branch, 27 miles; width at bottom $10\frac{1}{2}$ feet, average depth of cutting say 5 feet.		
$27 \times 5280 \times 5 \times (10\frac{1}{2}+5+2\frac{1}{2})$ = cubic feet ...	...	12,830,400
Cost.	Rs.	
12,830,400 cubic feet at Rs. 2 per 1,000	25,661	
Contingencies at 5 per cent.	1,283	
Total cost Rs....	26,944	

i.

Palegunj Branch, 14 miles; width at bottom 7 feet, depth of cutting say 4 feet on the average.		
$14 \times 5280 \times 4 \times (7+4+2)$ = cubic feet... ...	...	3,843,840
Cost.	Rs.	
3,843,840 cubic feet at Rs. 2 per 1,000	7,688	
Contingencies at 5 per cent....	384	
Total cost Rs....	8,072	

j.

Dinapoor Branch, 20 miles; width at bottom 14 feet, depth of cutting on the average say 7 feet.		
$20 \times 5280 \times 7 \times (14+7+3\frac{1}{2})$ = cubic feet ...	...	18,110,400
Cost.	Rs.	
18,110,400 cubic feet at Rs. 2 per 1,000	36,221	
Contingencies at 5 per cent.	1,811	
Total cost Rs....	38,033	

k.

Tikaree Branch above Jummoor Branch Head, 10 miles, escape 1 mile into Bootana, total 11 miles; width at bottom 26 feet, depth of cutting say 10 feet.		
$11 \times 5280 \times 10 \times (26+10+5)$ = cubic feet ...	...	23,812,800
Carried over		296,112,301

Brought forward		296,112,301
Cost.	Rs.	
23,812,800 cubic feet at Rs. 2-8 per 1,000	59,532	
Contingencies at 5 per cent.	2,976	
Total cost Rs....	62,508	

l.

Tikaree Branch below the Jummoor and above the Khurona Branch Heads, 5 miles (no escape); width at bottom 23 feet, average depth of cutting say 9 feet.

$5 \times 5280 \times 9 \times (23+9+4\frac{1}{2})$ = cubic feet		8,553,600
Cost.	Rs.	
8,553,600 cubic feet at Rs. 2-8 per 1,000	21,384	
Contingencies at 5 per cent.	1,069	
Total cost Rs.	22,453	

m.

Tikaree Branch between the Khurona and Achore Branch Heads, 11 miles, escape to Madar say 1 mile, total 12 miles; width at bottom 20 feet, average depth of cutting say 8 feet.

$12 \times 5280 \times 8 \times (20+8+4)$ = cubic feet...		16,220,160
Cost.	Rs.	
16,220,160 cubic feet at Rs. 2 per 1,000	32,440	
Contingencies at 5 per cent.	1,622	
Total cost Rs....	34,062	

n.

Tikaree Branch between the Achore and Dadur Branch Heads, 8 miles, (no escape); width at bottom 18½ feet, average depth of cutting say 8 feet.

$8 \times 5280 \times 8 \times (18\frac{1}{2}+8+4)$ = cubic feet		10,306,560
Cost.	Rs.	
10,306,560 cubic feet at Rs. 2 per 1,000	20,613	
Contingencies at 5 per cent.	1,030	
Total cost Rs....	21,643	

o.

Tikaree Branch between the Dadur and Hameednuggur Heads, 5 miles, no escape; width at bottom 17 feet, depth of cutting say 7 feet on the average.

$5 \times 5280 \times 7 \times (17+7+3\frac{1}{2})$ = cubic feet		5,082,000
Cost.	Rs.	
5,082,000 cubic feet at Rs. 2 per 1,000...	10,164	
Contingencies at 5 per cent.	508	
Total cost Rs. ...	10,672	
Carried over		336,274,621

	Brought forward ...	336,274,621

p.

Tikaree Branch between Hameednuggur and Kutangee Branch Heads, 4 miles, escape into the Salonee Nuddee say 2 miles, total 6 miles; width at bottom $14\frac{1}{2}$ feet, depth of cutting say 6 feet.

	$6 \times 5280 \times 6 \times (14\frac{1}{2}+6+3)$ = cubic feet		4,466,880
	Cost.	Rs.	
4,466,880	cubic feet at Rs. 2 per 1,000	8,934	
	Contingencies at 5 per cent.	447	
	Total cost Rs. ...	9,381	

q.

Tikaree Branch to end, 24 miles to tail escape; width at bottom 10 feet, depth of cutting say 6 feet on the average.

	$24 \times 5280 \times 6 \times (10+6+3)$ = cubic feet		14,446,080
	Cost.	Rs.	
14,446,080	cubic feet at Rs. 2 per 1,000	28,892	
	Contingencies at 5 per cent.	1,445	
	Total cost Rs. ...	30,337	

r.

Jummoor Branch, $6\frac{1}{2}$ miles; width at bottom 5 feet, depth say 4 feet on the average.

	$6\frac{1}{2} \times 5280 \times 4 \times (5+4+2)$ = cubic feet		1,510,080
	Cost.	Rs.	
1,510,080	cubic feet at Rs. 2 per 1,000	3,020	
	Contingencies at 5 per cent.	151	
	Total cost Rs. ...	3,171	

s.

Khurona Branch, 16 miles; width at bottom $10\frac{1}{4}$ feet, depth of cutting say 5 feet on the average.

	$16 \times 5280 \times 5 \times (10\frac{1}{4}+5+2\frac{1}{2})$ = cubic feet		7,497,600
	Cost.	Rs.	
7,497,600	cubic feet at Rs. 2 per 1,000	14,995	
	Contingencies at 5 per cent.	750	
	Total cost Rs. ...	15,745	

t.

Achore Branch, $5\frac{1}{2}$ miles; width at bottom 5 feet, depth of cutting say 4 feet on the average.

	$5\frac{1}{2} \times 5280 \times 4 \times (5+4+2)$ = cubic feet		1,277,760
	Cost.	Rs.	
1,277,760	cubic feet at Rs. 2 per 1,000	2,555	
	Contingencies at 5 per cent.	128	
	Total cost Rs. ...	2,683	
	Carried over		365,473,021

	Brought forward		365,473,021
	U.		
	Dadur Branch, 12 miles; width at bottom 7 feet, depth of cutting say 4 feet on the average.		
	12 × 5280 × 4 × (7 + 4 + 2) = cubic feet		3,294,720
	Cost.	Rs.	
3,294,720	cubic feet at Rs. 2 per 1,000	6,589	
	Contingencies at 5 per cent.	329	
	Total cost Rs. ...	6,918	
	V.		
	Hameednuggur Branch, 15½ miles; width at bottom 10 feet, depth of cutting say 5 feet on the average.		
	15½ × 5280 × 5 × (10 + 5 + 2½) = cubic feet		7,161,000
	Cost.	Rs.	
7,161,000	cubic feet at Rs. 2 per 1,000	14,322	
	Contingencies at 5 per cent.	716	
	Total cost Rs. ...	15,038	
	W.		
	Kutangee Branch, 15 miles; 9½ feet wide at bottom, depth of cutting say 5 feet on the average.		
	15 × 5280 × 5 × (9½ + 5 + 2½) = cubic feet		6,732,000
	Cost.	Rs.	
6,732,000	cubic feet at Rs. 2 per 1,000	13,464	
	Contingencies at 5 per cent.	673	
	Total cost Rs. ...	14,137	
	Grand total cubic feet of excavation in Eastern Soane Canal		382,660,741

NO. 1, EXCAVATION OF CHANNEL.

Part III. Lines for Navigation only.

	I.		
	Navigable line from the Dinapoor Branch Head to Patna, 27 miles, width at bottom 20 feet, depth of cutting say 6 feet on average.		
	27 × 5,280 × 6 × (20 + 6 + 3) = cubic feet		24,805,440
	Cost.	Rs.	
24,805,440	cubic feet of earth-work at Rs. 2 per 1,000 ...	49,611	
	Contingencies at 5 per cent.	2,485	
	Total cost Rs. ...	52,096	
	Carried over		24,805,440

Brought forward...		24,805,440

II.

Navigable Line from the Nansaugor Branch head to Arrah, 20 miles, width at bottom 20 feet, depth of cutting say 6 feet on average.

	$20 \times 5{,}280 \times 6 \times (20+6+3)$ = cubic feet		18,374,400
	Cost.	Rs.	
18,374,400	cubic feet of earth-work at Rs. 2 per 1,000	36,749	
	Contingencies at 5 per cent.	1,837	
	Total cost Rs. ...	38,586	

III.

Navigable Line from the Kochus Branch head to the Kurumnassa above the Railway Bridge, 27 miles, 20 feet wide at bottom and 6 feet deep.

	$27 \times 5{,}280 \times 6 \times (20+6+3)$ = cubic feet		24,805,440
	Cost.	Rs.	
	Same as Patna navigable line...	52,096	

IV.

Navigable Line from the Kuroundea Partiteur parallel to the Sasseram Branch as far as the head of the Main Navigation to Benares, 15 miles, 20 feet width at bottom and say 8 feet of excavation,

	$15 \times 5{,}280 \times 8 \times (20+8+4)$ = cubic feet		20,275,200
	Cost.	Rs.	
20,275,200	cubic feet at Rs. 2 per 1,000	40,550	
	Contingencies at 5 per cent.	2,027	
	Total cost Rs. ...	42,577	

V.

Main Navigable Line from the end of the above to the Ganges above Benares, 56 miles, 25 feet wide at bottom, depth of cutting 10 feet on average

	$56 \times 5{,}280 \times 10 \times (25+10+5)$ = cubic feet		118,272,000
	Cost.	Rs.	
118,272,000	Cubic feet Excavation at Rs. 2-8 per 1,000 ..	2,95,680	
	Contingencies at 5 per cent.	14,784	
		3,10,464	
	Grand Total cubic feet of Excavation in Lines for Navigation only		206,532,480

Note to the Estimate of the cost of Excavation.

The mean depths entered in the column of the Estimates of the channels of which detailed levels have been taken are not arithmetical means on which the calculation of quantities are based; on the contrary these means are deduced from the quantities calculated from sections in which the depth is given at every 100 feet.

The berm has not been cut to an uniform height above the water line, but left at the level of the ground, excepting in cutting of greater depth the 15 feet where it is placed at 8 or 10 feet above water line as shown in Plate XXI.

The following Table gives an analysis of the rates. It is based on the sections given in Plate XXI., the "lift" being the calculated height of the centre of gravity of the spoil bank above the centre of gravity of the excavation, and the "lead" being the horizonted distance of the centre of gravity of the spoil bank from the centre of gravity of the half channel.

The rates used in the estimate are higher than those given in the table; a margin being allowed for difficulties arising from the nature of the soil, &c. In the deep cutting this is considerable, being abovt 1¼ Rs.; for the rest it is ½ a Rupee. The rates are taken at 4 Rs., 2½ Rs. and 2 Rs., as divided off by lines in the Table. The rate on the upper part of the Sasseram Branch, however, is taken at 3 Rs. per 1,000.

By Coulomb's experiments the labour expended by a man in digging the ground, in raising a maximum weight 10 feet, and in carrying it 100 feet, are nearly as 8½, 9½ and 17½ respectively. The cost is inversely as these numbers. The prices inserted in the headings of the columns are taken from Lieut. Col. A. G. Goodwyn's Ganges Canal rates, with the modifications necessary to suit this form of table. His rates so modified agree very well with the rates deduced from Coulomb's experiments. I have taken the dressing as digging to a depth of 6 inches, *including the berms.*

TABLE.

Sections of Plate XXI.	Excavation at the rate per 1,000 feet.	Lift at per 10 feet annas 12 per 1,000 feet. Height.	Lift ... Cost.	Lead at per 100 feet annas 6¼ per 1,000 cubic feet. Distance.	Lead ... Cost.	Dressing at per 1,020 supl. feet ans. 6½ equal 6 inches digging. Proportion per 1,000 cubic feet.	Dressing ... Cost.	Total cost per 1,000 cubic feet.
	R. A.		R. A.		R. A.		R. A.	R. A.
Deep cutting Western Canal	0 13	14·2	1 1	184·5	0 12	200	0 1·3	2 11·3
Ditto Eastern ditto ...	0 13	15·0	1 2	163·2	0 10·6	190	0 1·23	2 10·85
Channel, Class I. ...	0 13	7·6	0 9·1	114·0	0 7·4	366	0 2·4	1 15·9
II. ...	0 13	7·9	0 9·5	87·1	0 5·7	374	0 2·4	1 14·6
III. ...	0 13	8·7	0 10·4	84·4	0 5·5	298	0 1·8	1 14·7
IV. ...	0 13	7·0	0 8·4	63·8	0 4·1	449	0 2·9	1 12·4
V. ...	0 13	5·3	0 6·3	57·2	0 3·7	645	0 4·2	1 11·2
VI. ...	0 13	5·0	0 6·0	54·5	0 3·5	659	0 4·3	1 10·8
VII. .	0 13	4·1	0 4·9	41·3	0 2·7	790	0 5·1	1 9·7
VIII. ...	0 13	3·7	0 4·4	37·5	0 2·4	968	0 6·3	1 9·4
IX. ...	0 13	3·0	0 3·6	29·1	0 1·9	1,054	0 6·8	1 9·3
X. ...	0 13	2·2	0 2·4	24·6	0 1·6	1,709	0 10·1	1 11·1

A. Permanent Dam.

	No.	L.	B.	D.	Products.
Masonry.					
Foundation Blocks 13 x 7 x 10 exterior diversion—					
Double line across Soane 9,600 feet ... 1,422					
Single line in rear of west sluices and on flank .. 33					
Ditto eastern ditto ... 23					
	1,478	Section. (13 x 7—10 x 4)		17	1,281,426
Main wall 9600—(357 + 213) ...	1	9,030	$\frac{6+8}{2}$	6	379,260
Wing walls of Dam sluices ...	2	43	4	$\frac{4+7}{2}$	1,892
		(Mean length.)			
Flooring western sluices ...	1	360	93	2	66,960
Flooring eastern sluices ...	1	216	93	2	40,176
Concrete under flooring in ditto ...	...	570	71½	3	122,265
Piers western 39, eastern 23—					
Body under road-way ...	62	23	3	7	29,946
1st Step ...	62	2	3	8	2,976
2nd " ...	62	2	3	7	2,604
3rd " ...	62	2	3	6	2,232
4th " ...	62	2	3	5	1,860
5th " ...	62	2	3	4	1,488
6th " ...	62	2	3	3	1,116
7th " ...	62	2	3	2	744
8th " ...	62	2	3	1	372
Road-way western 357, eastern 213	...	570	23	2	26,220
Total Masonry ...	...	...	...	...	1,961,537
Dry Stone-work.					
Rough stone Apron of Dam proper	1	9,030	135	10	12,190,500
Ditto western sluices ...	...	357	90	8	257,040
Ditto eastern ditto ...	1	213	90	8	153,360
Total Dry Stone-work ...	...	...	...	...	12,600,900
Iron-work.					
Iron-work for securing road-way over Dam sluices—					
Under bars ...	128	25	$\frac{1}{12}$	$\frac{1}{12}$	22·222
Over bars including join ...	128	21	$\frac{1\frac{1}{2}}{12}$	$\frac{1\frac{1}{2}}{12}$	42·000
Tie rods ditto ...	256	10	0·7854	$(\frac{1}{16})^2$	7·854
Pins ...	256	$\frac{1}{4}$	0·7854	$(\frac{1}{16})^2$	0·196
Nuts ...	256	$\frac{2}{12}$	$\frac{2}{12}$	$\frac{3}{48}$	0·444
Total cubic feet of Iron ...	...	...	...	...	72·7
Or Cwt. ...	...	...	...	...	312½

A. Permanent Dam,—concluded.

	No.	L.	B.	D.	Products.
Wood-work.					
Stop boards for dam sluices at 6 to each opening ...	384	10	1	$\frac{2}{12}$	640
Total cubic feet planks ...	...	...	...	...	...
Clay Puddle.					
Ditto in front of wells of dam ...	1	9,600	20	5	960,000
Ditto rear of well of sluice flooring	1	700	15	5	52,500
Total ...	...	...	...	...	1,012,500

ABSTRACT.

		Rs.
1,961,537	Cubic feet of masonry (selected rubble) at 15 per 100 ...	2,94,230
26,220	" of road-way beams extra cost at 15 " ...	3,933
12,600,900	" of dry stone-work in aprons at 4 " ...	5,04,036
1,478	Curb for masonry blocks at 25 each	36,950
1,478	Blocks, sinking at 100 each	1,47,800
312½	Cwt. of wrought-iron work at 20 each	6,250
640	Cubic feet of planking of saul at 3 per cubic foot ...	1,920
1,012,500	" clay puddle at 3 per 100	30,375
	Excavating sand and turning streams, say	50,000
	Contingencies at 5 per cent.	53,775
	Total Permanent Dam, Co.'s Rs. ...	11,29,269

B. Temporary Dam.

Two lines of 15 feet piles each 12,000 feet long across the river. The piles of each line to be driven close, and the two lines to be 20 feet apart. The lines to form an angle salient to the stream, so as to direct the current towards the sides.

	Rs.
Say 2 piles to the foot, or 48,000 in all, at 2 Rs. each, including driving	96,000
Clay puddle between the piles and 20 feet below the lower line 4 feet deep. 40 × 4 × 12,000 = 1,920,000 cubic feet at Rs. 3 per 100	57,600
Dry stone covering for ditto. 40 × 2 × 12,000 = 960,000, at Rs. 4 per 100	38,400
Extra clay puddle at sides for bridges, say 40 × 4 × 1,000 as before = 160,000, at Rs. 3	4,800
Ditto stone covering 40 × 2 × 1,000 = 80,000, at Rs. 4	3,200
Trestle bridges, 400 feet on west and 250 on east, at Rs. 20 per foot...	13,000
Stop boards of coarse jungle wood, 650 × 6 × 1 × 0·1, at Rs. 2	780
Contingencies at 5 per cent....	10,689
Total Temporary Dam, Co.'s Rs. ...	2,24,469

A. Western Soane Canal.

Masonry.	No.	L.	B.	D.	Products.
Foundation Blocks.					
Large blocks under piers of bridge	8	(15 × 7 − 12 × 4)		17	7,752
Small ditto and under centre and ends of bridge	12	(9·5 × 7 − 6·5 × 4)		17	8,262
Ordinary ditto ditto in centre of centre walls	2	(11 × 7 − 8 × 4)		17	1,530
Figured on general Plan.					
Upper curved steps 6					
Between bridge and dam ... 7					
Below dam 14					
Figured in separate half Plan.					
Twice the number figured under half bridge 90					
Figured for junction of dam and steps 9	126	(13 × 7 − 10 × 4)		17	1,09,242
Main Bridge.					
Flooring under bridge, including piers but not abutments, the starlings of the latter ..	1	202	40	2	16,160
Ditto in front of bridge, including starlings	1	210	22	2	9,240
Ditto ditto, portions next to curve of steps	2	22 × 22 × (1 − 0·78)		2	426
Ditto in rear of bridge, including starlings	1	210	78	2	32,760
Piers and abutments between starlings up to spring of arch ...	10	35	5	14	24,500
Starlings up to ditto	20	2·5 × 2·5	0·78 ÷ 2	14	682
Abutments backing river side of centre wall	2	19·5	3	25	2,925
Ditto in rear of ditto	2	13	1	12	312
Ditto ditto	2	12·5	1	9	225
Ditto ditto	2	14	1	6	168
Abutments, straight wings or buttresses	4	9	6	25	5,400
Ditto ditto	4	3	4	25	1,200
Ditto ditto	4	5	4	20	1,600
Ditto ditto	4	6	3	15	1,080
Curved wings	2	16	3	25	2,400
Ditto	2	8	3	17	816
Ditto	2	7	3	11	462
Ditto	2	3·5	2	11	154
Ditto pillar	2	2·5	2·5	11	137
Sluice piers	21	12·5	2	8	4,200
Starlings to ditto	42	2 × 2	·78 ÷ 2	8	524
Ditto above ditto	21	25· × 2·5	·78 ÷ 2	6·5	332
Ditto ditto to receive groove ...	21	0·5	2	6·5	136
Carried over ...	...	......	......	......	232,625

Masonry.	No.	L.	B.	D.	Products.
Brought forward ...	...	......	......	......	232,625
Sluice wall below spring of arch...	7	18	10	6·5	8,190
Ditto in arches	7	18^2	$\frac{7854}{2}$	8·5	7,570
Arches	9	10 × 3·14	35·5	2	20,064
Solid spandrills in front of middle wall	9	11 × 22 × (1 − 0·78)		17·5	8,385
Portions above centre of piers ...	8	1	17·5	11	1,540
Ditto behind abutment	2	6	17·5	11	2,310
Two spandrill walls behind centre wall	14	11 × 22	(1 − 78)	2	1,490
Flooring of roadway of bridge between ditto	14	13	6	1·5	1,638
Backing up behind abutments ...	2	3	12	11	792
Ditto over piers	8	7 ÷ 2	12	6·5	2,181
Centre wall of bridge	1	265	2	4	2,120
Terminal blocks of ditto... ...	2	3 × 3	0·78 × 2	4	112
Front parapet of bridge	1	265	1·5	4	1,590
Ditto blocks of ditto	2	2	2	4	32
Rear parapet of bridge	1	212	2	4	1,696
Extra quantity for taking parapet round starlings...	20	(3·14 ÷ 2 − 1) × 3·5		2 × 4	319
Parapet of curved wing walls ...	2	314 ÷ 3	18 × 2	4	302
Small Bridge over Roadway.					
Abutments, first	2	19	11	3	1,254
second	2	19	10	5	1,900
third	2	19	8	6	1,821
fourth	2	19	6	2	456
fifth	2	19	55	1	2,090
Ditto backing up behind arch ...	2	19	5	4	760
Arch	1	20·6	19·5	2	801
Spandrill solid	1	(4 × 18·75)	(1—0·71)	× 19	315
Rear wing walls	2	10	2	18	720
Ditto	2	20	2	11	880
Starlings in rear	2	3 × 3	0·78 ÷ 2	16	113
Parapet to bridge and wing walls in rear	1	18	1·5	4	108
Ditto over wing walls	2	16 × 3·17 ÷ 2 × 1·5		4	135
Ditto over starlings	2	28 × 2·5	3·78 ÷ 2	4	1,058
Ditto dwarf pillars	2	2	2	4	32
Steps in rear of Bridge, including foundations of rear wing wall—					
3 lowest steps	2	38	3	5	1,140
3 next	2	38	3	4	912
4 next	2	35	4	4·5	1,260
4 next	2	27	(4 × 4·5)	(2 × 2)	756
Top walls	2	18	2	11	792
Parapet	2	30	1·5	3	272
Carried over ...	...	......	......	......	309,947

Masonry.	No.	L.	B.	D.	Products.
Brought forward ...	...	... ..	......	......	309,947
Steps in rear of Main Bridge.					
Lower steps and covering over walls	2	80	7	3	3,360
Six steps above the lowest ...	2	80	6	3·5	3,360
Two next	2	77	2	5·5	1,694
Two next	2	75	2	4·5	1,350
Three next...	2	72	3	4	1,728
Three next...	2	68	3	4	1,632
Four next	2	61	5	5	3,050
Three next...	2	53	3	4	1,272
Top steps and walls	2	40	(3 × 11—2 × 2)		2,320
Parapets below steps	2	$17 \times \frac{3.1416}{3}$	× 1·5	3	160
Dwarf pillars at end	4	2	2	3	48
Steps along river bank.					
Four gradients forming complete circle—					
Lower 7 steps	1	3·14 × 24	5	7	2,638
Next 2	1	3·14 × 36	2	5·5	1,244
Next 2	1	3·14 × 32	2	4·5	904
Next 3	1	3·14 × 27	3	4	1,017
Next 3	1	3·14 × 21	3	4	791
Next 4	1	3·14 × 14	4	4·5	791
Next 4	1	3·14 × 6	(4 × 4)—(2 × 2·5)		207
Centre Walls	4	2	2	11	176
Short piece above bridge—					
Lower 7 steps	1	36	5	7	1,260
Next 2	1	36	2	5·5	396
Next 2	1	36	2	4·5	324
Next 3	1	36	3	4	432
Next 3	1	36	3	4	432
Next 4	1	36	4	4·5	648
Next 4	1	36	(4 × 4—2 × 2·5)		396
Inner wall	1	36	2	11	792
Dwarf Pillar	1	2	2	4	16
Long piece below bridge, taken over all to cover expense of retaining walls and pavement at roadway—					
Lower 7 steps	1	340	5	7	11,900
Next 2	1	340	2	5·5	3,740
Next 2	1	340	2	4·5	3,060
Next 3	1	340	3	4	4,080
Next 3	1	340	3	4	4,080
Next 4	1	340	4	4·5	6,120
Next 4	1	340	(4 × 4—2 × 2·5		3,740
Inner wall	1	340	2	11	7,480
Parapet	1	310	1·5	4	1,860
Extra thickness for pilasters	1	54	0·5	4	108
Grand Total Masonry	...	...	...	...	388,543

Masonry.	No.	L.	B.	D.	Products.
Earth-work.					
Excavation at head in excess of which is provided for in Channel Estimate.					
First	1	142	138	17	333,132
Second	1	140	$\frac{138}{2}$	17	164,220
Embankments along Soane bank...	1	5,000	33·5 mean	10	1,675,000
Excavation for Roadway	1	240	30	5	36,000
Total Earth Work...	..	...	...	...	2,208,352
Dry Stone Protective Works.					
Along river bank	1	5,000	5	30	750,000
Flooring inside bridge	1	mean 160	94	5	75,200
Inside lower part of roadway slopes	2	100	3	10	6,000
Total Dry Stone Work ...	...	...	...	...	831,200
Concrete.					
Flooring under Bridge	1	202	40	3	24,240
Do. in part of Bridge ...	1	210	22	3	13,860
Do. near curved steps ...	2	22 x 22	(1–·078¼)	3	306
Do. in rear of Bridge ...	1	210	78	3	49,140
		...	..	...	87,546
Deduct Space occupied by Blocks—					
First	8	15	7	3	2,520
Second	12	9·5	7	3	2,394
Third	2	11	7	3	462
Fourth	77	13	7	3	21,021
					26,397
Total Concrete Work...	...	...	...	...	61,149
Sluice Gates.					
Side gates, large	2	26	19	0·75	741
Sluice gates, small	28	8	2·5	0·17	95
Total ... [Rate to cover cost of apparatus.]	...	...	...	...	836

Masonry.	No.	L.	B.	D.	Total.
Metalling.					
Whole length of work ...	1	689	30	0·5	10,335
Roadway to river	1	500	16	0·5	4,000
	...	...	...	...	14,335
Cut-stone work.					
Grooves for side gates ...	4	26	1	1	104
Heads of sluice piers with grooves	21	15	2	2	1,260
Coping of all parapets, say (see lengths of parapets). ...	1	1,031	2	0·5	1,031
String course of ditto ...	...	1,031	1	0·5	516
String course of bridge piers and abutment	10	80	1	0·5	400
Outer face of arches ...	18	19 × 3·14 + 2 × 2		2	2,148
Total cut-stone work ...	...	...	...	...	5,459
(The steps are merely of coursed, not cut-stone).					

ABSTRACT.

		Rs.
2,208,352	Earth-work at Rs. 6 per 1,000	13,250
366,193	Masonry at Rs. 15 per 100	55,151
20,868	Arching at Rs. 25 per ditto	5,217
148	Curbs for blocks at Rs. 25 each	3,700
148	Sinking blocks at Rs. 100 each	14,800
831,120	Dry stone work at Rs. 4 per 100	33,244
61,149	Concrete work at Rs. 12 per 100	7,337
5,459	Cut-stone work (extra charge) Rs. 30 per 100	1,638
14,335	Metalling at Rs. 6 per 100	860
836	Cubic feet sluice gates, apparatus inclued, at Rs. 5 per cubic foot	4,180
	Contingencies at 5 per cent.	6,969
	Total cost of Head Works, Western Soane Canal, Co.'s Rs. ...	1,46,346

N. B.—Of this sum the following is for protective works along the Soane bank for one mile, viz.:—

		Rs.
1,675,000	Cubic feet embankment at Rs. 6	10,050
750,000	Ditto dry stone work at Rs. 4	30,000
	Contingencies...	2,002
	In all Rs. ...	42,052

No. 3, Head Works.—B. Eastern Soane Canal.

	No.	L.	B.	D.	Total.
Main Bridge.					
Flooring under bridge, including piers but not abutments, nor the starlings of piers	1	156	40	2	12,480
Ditto in front of bridge, including starlings	1	164	22	2	7,216
Ditto ditto portions next to curve of steps	2	22×22	(1−0·7854)	2	315
Ditto in rear of bridge, including starlings	1	164	78	2	25,584
Piers and abutments between starlings up to spring of arch...	8	35	5	12·5	17,500
Starlings up to ditto ...	16	2·5×2·5	0·78×2	12·5	1,950
Abutments backing of centre wall river side	2	19·5	3	23·5	2,749
Ditto in rear of ditto ...	2	13	1	12	312
Ditto	2	13·5	1	9	243
Ditto	2	14	1	6	168
Abutments, straight wings or buttresses	4	9	6	23·5	5,076
Ditto ditto ...	4	3	4	23·5	1,128
Ditto ditto ...	4	5	4	18·5	1,480
Ditto ditto ...	4	6	3	13·5	972
Curved wings	2	16	3	23·5	2,256
Ditto	2	8	3	15·5	744
Ditto	2	7	3	11	462
Ditto	2	3·5	2	11	154
Ditto Pillar	2	2·5	2·5	11	137
Sluice piers	15	12·5	2	6·5	2,437
Starlings to ditto	30	2×2	·7854+2	6·5	306
Ditto above ditto	15	2·5×2·5	·78+2	5·5	201
Ditto ditto to receive groove ...	15	0·5	2	5·5	82
Sluice wall below spring of arch...	5	1·8	10	5·5	4,950
Ditto in arches... ...	5	18×18	·78+2	5·5	3,475
Arches	7	10×3·14	355	2	15,606
Solid spandrills in front of middle wall	7	11×22	(1−0·78)	17·5	6,522
Portions above centre of piers ...	6	1	17·5	11	1,155
Ditto behind abutments ...	2	6	17·5	11	2,310
Two spandrill walls behind centre walls	14	11×22	(1−·78)	3	1,490
Flooring of roadway of bridge between centre walls ...	14	mean 13	6	1·5	1,638
Backing up behind abutments ...	2	mean 3	12	11	792
Over piers	6	7+2	12	6·5	1,638
Parapet of curved wing walls ...	2	3·14+3×18×1·5		4	299
Centre wall of bridge ...	1	219	2	4	1,752
Terminal blocks of ditto ...	2	3+3×0·78+2		4	28
Front parapets of bridge ...	1	219	1·5	4	1,314
Terminal blocks of ditto ...	2	2	2	4	32
Rear parapet of bridge ...	1	166	1·5	4	996
Carried over ...	...	...	......	......	1,27,939

	No.	L.	B.	D.	Total.
Brought forward ...	...	......	......	......	1,27,939
Extra quantity for taking parapet round starlings	16	(3·14+2—1) × 3·5		1·5 × 4	191
Small Bridge over Roadway.					
Abutment, first	2	19	11	8	3,344
second	2	19	10	5	1,900
third	2	19	8	6	1,824
fourth	2	19	6	2	456
fifth	2	19	5·5	1	209
Ditto backing up behind arch	2	19	5	4	760
Arch	1	20·6	19·5	2	804
Spandrill solid	1	(4 × 18·75)	(1—0·78) × 19		313
Rear wing walls	2	10	2	18	720
Ditto ditto	2	20	2	11	880
Starlings in rear	2	3 × 3 × 0 78+2		16	112
Parapets to bridge and wing walls in rear.—Over bridge ..	1	18	1·5	4	108
Over wing walls ...	2	16 × 3·14+2	1·5	4	301
Over starlings ...	2	2·5 × 2·5 × ·78+2		4	19
Dwarf pillars ...	2	2	2	4	32
Steps in rear of bridge including foundation of rear wing wall—					
Three lowest steps ...	2	38	3	5	1,140
Three next	2	38	3	4	912
Four next	2	35	4	4½	1,260
Four next	2	27	(4 × 4·5)—(2·5 × 2)		702
Top walls	2	18	2	11	792
Parapet	2	30	1·5	3	270
Steps in rear of Main Bridge.					
Lower steps and covering over wells	2	80	7	3	3,360
Six steps above the lowest ...	2	80	6	3·5	3,360
Two next	2	77	2	5·5	1,694
Two next	2	75	2	4·5	1,350
Three next	2	72	3	4	1,728
Three next	2	68	3	4	1,632
Three next	2	61	3·5	3·5	1,494
Three next	2	53	3	4	1,272
Top steps and walls	2	40	(3 × 11—2 × 2)		2,320
Parapets below steps ...	2	17 × 3·14+3 × 1·5		3	159
Dwarf pillars at ends ...	4	2	2	3	48
Total Masonry ...	...	...	...	...	1,63,405
Earth-work.					
Excavation at head in excess of what is provided for in Channel Estimate—					
First	1	140	72	17	1,71,360
Second	1	140	72/2	17	85,680
Excavation for Roadway ...	1	240	mean 30	5	36,000
Total Earth-work ...	...	...	...	...	1,93,040

	No.	L.	B.	D.	Total.
Cut Stone-work.					
Grooves for side gates ...	4	24·5	1	1	98
Heads of sluice piers with grooves	15	12	2	2	720
Coping of all parapets, see length of parapets in Masonry ...	1	724	2	0·5	724
String course of ditto ...	1	724	1	0·5	362
——— of piers and abutments	8	80	1	0·5	320
Outer face of arches... ...	14	$\frac{19 \times 3{\cdot}14}{2}$	2	2	1,671
Total Cut Stone-work ...	...	...	...	...	3,895
Metalling.					
Along bank including bridge, say	1	400	30	0·5	6,000
Roadway to river	1	400	16	0·5	3,200
Total Metalling ...	...	...	...	...	9,200
Sluice Gates.					
Side gates, large	2	24·5	19	0·75	698
Sluice gates in arches ...	20	6·5	2·5	0·17	55
Total cubic feet Sluice Gates ...	...	...	...	...	753

ABSTRACT.

			Rs.
193,040	Cubic feet of	Excavation at Rs. 6 per 1,000	1,158
146,995	ditto	Masonry at Rs. 15 per 100	22,049
16,410	ditto	ditto in Arch at Rs. 25 per 100	4,102
3,985	ditto	Cut Stone-work (extra charge) at Rs. 30 per 100...	1,195
9,200	ditto	Metalling ditto at Rs. 6 per 100 ...	552
753	ditto	Sluice gates with apparatus at Rs. 5 per cubic foot	3,765
	Contingencies at 5 per cent.	... ...	1,641
		Total cost of Eastern Soane Canal Head Works, Rs. ...	34,462

A. Western Lock Channel Head.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	6	(7 × 7)—(4 × 4)		14	2,772
	2	(8 × 7)—(5 × 4)		14	1,008
	4	(11 × 7)—(8 × 4)		14	2,520
	187	(13 × 7)—(10 × 4)		14	1,33,518
Flooring all under body of works.	1	210	192	2	80,640
Ditto in covering in blocks below tail of piers	2	25	7	2	700
Ditto behind abutments beyond line of counter-forts.					
Tail bridge	2	11+7	7	2	504
Head bridge	2	20	5	2	400
Ditto	2	13	7	2	364
Ditto under side steps	16	13	7	2	2,912
Lock chamber walls	4	153	10	26	1,59,120
Semi-circular ends	4	10^2	$\frac{0{\cdot}7854}{2}$	26	4,084
Centre projections	2	mean 16	9	26	7,488
	...	......	......	......	3,96,030
Deduct—Hollows for lock gates ...	8	12	1	26	2,496
Hollow in centre walls...	2	153—20	3	4	3,192
Also backing behind arch	2	19	(2 + 6)0·5 × 6		912
and parts of arch ... {	2	19	10	3	1,140
	2	19	$\frac{1}{2}$	2	266
Above footing outer wall	2	123	2	9	4,428
	...	......	......	......	12,434
Counter-forts	10	6	4	26	3,83,596
Buttresses at flanks	4	12	(8 × 4)0·5 × 26		7,488
Front wing walls (straight) 1st ...	2	9	8	26	3,744
2nd ...	2	7	6	26	2,184
3rd ...	2	11	4	12	1,056
Rear wing walls curved, 1st ...	2	$\frac{53 \times 3{\cdot}1416}{12}$	6	26	4,337
2nd ...	2	$\frac{51 \times 3{\cdot}1416}{12}$	4	17	1,816
3rd ...	2	$\frac{49 \times 3{\cdot}1416}{12}$	2	10	513
Sluice wall, below pillar ...	4	3	3	10	360
1st	1	104	8	11	9,152
2nd	1	104	10	6	6,240
3rd	4	5	12	8	1,920
4th	15	2	12	8	2,880
Piers of head bridge, 1st	4	23—12	5	8	1,760
2nd	4	23—10	5	6	1,560
Starlings ...	8	$5^2 \times {\cdot}7854 + 2$		26	2,042
Heads of sluice piers ...	15	$2^2 \times {\cdot}7854 + 2$		15	253
Ditto space for grooves ...	15	$4\frac{1}{2}$	$\frac{1}{2}$	15	506
Carried over ...	..	......	......	......	4,37,639

	No.	L.	B.	D.	Total.
Brought forward ...	...	...	......	......	4,37,639
Arching head bridge ...	5	$\frac{20 \times 3{\cdot}1416}{2}$	15	2	4,742
Spandrills head bridge ...	$(110 \times 15 \times 11) - 5 \times 22^2 \times \frac{0{\cdot}7854}{2} \times 15)$				3,900
Tail bridge Piers ...	4	19	5	14	5,320
Starlings ..	8	$\frac{5^2 \times {\cdot}7854}{2}$	...	26	2,042
Arching (centre arches)	5	$\frac{20 \times 3\ 1416}{2}$	19	2	5,969
Backing behind arches	4	$\frac{6}{2}$	7	11	924
Spandrill walls ...	4	$(110 \times 11 - 5 \times 22^2 \times \frac{{\cdot}7854)}{2} \times 12$			2,880
Arching side arches ...	2	$\frac{18 \times 3{\cdot}14}{2}$	19	2	2,149
Spandrills to ditto ...	2	10	$9 \times 0{\cdot}5$	8	720
Steps in rear of bridge—					
1st 3 Steps ...	2	60	5	4	2,400
Next 3 " ...	2	59	$(6+4) \times 0{\cdot}5$	3	1,770
3 " ...	2	58	$(6+4) \times 0\ 5$	3	1,740
3 " ...	2	56	$(6+4) \times 0{\cdot}5$	3	1,680
3 " ...	2	53	$(6+4) \times 0{\cdot}5$	3	1,590
3 " ...	2	48	$(7+5) \times 0\ 5$	3	1,728
3 " ...	2	41	$(4+2) \times 0\ 5$	3	738
Remainder ...	2	32	$(6+3) \times 0\ 5$	4	1,152
Wall under top ...	2	28	3	1½	252
Ditto ditto ...	2	28	2	3½	392
Steps on Soane bank, 4 quadrants making a circle—					
Lowest steps ...	3·1416	24+18½	0 5×5	4	1,335
Next " ...	3 1416	22+20	0 5×5	3	989
3 ...	3 1416	19+17	0·5×5	3	848
3 ...	3·1416	16+14	0·5×5	3	707
3 ...	3·1416	13+11	0·5×5	3	565
3 ...	3 1416	10½+8½	0·5×6	3	537
3 ...	3 1416	7½+5½	0·5×3	3	184
Remainder ...	3 1416	2½	4½	4	141
Steps on Soane bank, straight portion ..	2	60	5	4	2,400
	2	60	5	3	1,800
	2	60	5	3	1,800
	2	60	5	3	1,800
	2	60	5	3	1,800
	2	60	5	3	1,800
	2	60	3	3	1,080
	2	60	4½	4	2,160
Walls ...	2	63	3	1½	567
Ditto ...	2	69	2	3½	882
Carried over ...	...	.....	.....	......	5,01,092

	No.	L.	B.	D.	Total.
Brought forward ...	...	......	...	...	5,01,092
Parapets, curved wings	4	24 × 0·5 + 3·14 × 3		1½	678
Heads of lock walls...	8	3·14 × 8½	3	1½	336
Ditto piers	16	$\frac{3 \cdot 1416}{2}$	4 × 3	1½	452
Crossing lock channel	4	16	3	1½	288
Crossing arches ...	20	18	3	1½	1,620
Sides of lock chamber	4	132	3	1½	2,376
Sides of bason, front of bridge	2	12	3	1½	108
Rear of bridge round curve	2	106	3	1½	954
Front steps	2	22	3	1½	198
Dwarf pillar	8	2	2	3	96
Total Masonry ...	...	...	...	...	508,822
Dry Stone-work.					
At tail	1	180	45	3	24,300
Concrete Work.					
Lock chambers	2	105·5	13·5	3	8,545
Between bridges	1	104	90	3	28,080
At tail	1	104	23·5	3	7,332
Ditto	2	35·5	21·5	3	4,579
Between piers, tail bridge ...	2	22	14	3	1,848
Ditto ditto	2	27	15	3	2,430
Ditto ditto	3	27	16	3	3,888
Ditto head bridge...	3	13·5	16	3	1,944
Ditto ditto	2	13·5	15	3	1,215
Ditto ditto	2	13·5	7·5	3	607
Front of head bridge	1	52	23·5	3	3,666
Ditto	2	36	10	3	2,160
	...	...	...	...	66,294
Deduct—Projection of wells in centre	2	14·5	13·5	3	1,174
And	2	7·5	7·5	3	337
	...	...	...	..	1,511
Total	...	...	...	...	64,783
Cut Stone-work.					
Seat for lock gate pivots	8	26	2	2	832
Heads of sluice piers ...	15	15	2	2	900
Coping of all parapets (see lengths of parapets in masonry) ...	1	1,603	2	0·5	1,603
String course of ditto	1	1,603	1	0·5	802
Carried over ...	...	...	...	...	4,137

	No.	L.	B.	D.	Total.
Brought forward ...	...	...	...	...	4,137
String course of bridge piers and abutments	16	40	1	0 5	320
Outer faces of arches	24	31½	2	2	3,024
Total ...	...	...	..	...	7,481
Excavation.					
Say	1	250	100	23	5,75,000
And	1	200	50	18	1,80,000
Total Excavation ...	...	...	...	...	7,55,000
Metalling.					
1st Bridge	1	104	16	0 5	832
2nd "	1	180	16	0 5	1,440
Sides of lock chambers	2	150	32	0 5	4,800
Total ...	...	...	...	...	7,072
Gates.					
Lock gates, 4 pairs, or	8	0·75	10	26	1,560
Sluice gates	20	0·17	2 5	8	68
Total ...	...	...	...	...	1,628
Drum sluices	10				

ABSTRACT.

		Rs.
7,55,000	Excavation, at Rs. 6 per 1,000	4,530
199	Curb frames for blocks, at Rs. 25 each	4,975
4,95,992	Cubic feet masonry, at Rs. 15 per 100	74,399
199	Blocks, sinking, at Rs 100 each	19,900
12,830	Of arch work, at Rs 25	3,207
64,783	Concrete work, at Rs. 12	7,774
24,300	Dry stone-work, at Rs. 4	972
7,481	Cut stone-work (extra charge), at Rs. 30	2,244
7,072	Metalling, at Rs. 6	424
1,628	Cubic feet gates, with apparatus, at Rs. 5 per foot	8,140
10	Drum sluices, at Rs. 100 each	1,000
	Contingencies at 5 per cent.	6,378
	Total cost of Western Lock Channel Head, Co.'s Rs ...	1,33,943

B. Eastern Lock Channel Head.

	No.	L.	B.	D.	Total.
Flooring all under body of works	1	210	146	2	61,320
Ditto behind abutments, beyond line of counterforts	2	11×7	7	2	504
Lock chamber walls	4	153	10	24·5	1,49,940
Semi-circular ends	4	$\frac{10^2 \times \cdot 7854}{2}$		24·5	3,848
Centre projections	2	16	9	24·5	7,056
					2,22,668
Deduct—Hollows for lock gates	8	12	1	24·5	2,352
Ditto in centre walls ...	2	(153—20)	3	4	3,192
Above footing outer wall	2	123	2	9	4,428
Backing behind arch ...	2	19	$\frac{2+6}{2}$	6	912
Do.	2	19	10	3	1,140
Part of arch	2	19	$\frac{1}{2}$	2	266
					12,290
					2,10,378
Counterforts	10	6	4	24·5	5,880
Buttresses at flanks	4	12	$\frac{8+4}{2}$	24·5	7,056
Front wing walls, 1st	2	9	8	24·5	3,728
2nd	2	7	6	24·5	2,058
3rd	2	11	4	12	1,056
Rear wing walls curved, 1st ...	2	$\frac{53 \times 3 \cdot 1416}{12}$	6	24·5	4,079
2nd ...	2	$\frac{51 \times 3 \cdot 1416}{12}$	4	17	1,816
3rd ...	2	$\frac{49 \times 3 \cdot 1416}{12}$	2	10	513
Below pillar ...	4	3	3	10	360
Sluice wall, 1st	1	52	$6\frac{1}{2}$	11	3,718
2nd	1	52	10	6	3,120
3rd	2	5	12	8	960
4th	9	2	12	8	1,728
Piers of head bridge, 1st ...	2	23—12	5	8	880
2nd ...	2	23—10	5	6	780
Starlings	4	$\frac{5^2 \times \cdot 7854}{2}$	...	24·5	952
Heads sluice piers...	9	$\frac{2^2 \times \cdot 7854}{2}$	...	13	183
Ditto spaces for grooves... ...	9	$4\frac{1}{2}$	$\frac{1}{2}$	13	263
Arching head bridge	8	$20 \times \frac{3 \cdot 1416}{2}$	15	2	2,827
Spandrills, head bridge	$(64 \times 15 \times 11)—(3 \times 22^2 \times \frac{0 \cdot 7854}{2} \times 15) = 2{,}007$				
Tail bridge, piers	2	19	5	12	2,280
Starlings	4	$\frac{5^2 \times \cdot 7854}{2}$	...	24·5	952
Carried over ...	...	.....	......	......	2,57,574

	No.	B.	D.	L.	Total.
Brought forward ...	...	......	......	......	2,57,574
Arching	3	$\frac{20 \times 3{\cdot}1416}{2}$	19	2	3,572
Backing behind arches	2	$\frac{6}{2}$	7	15	462
Spandrill walls	4	$(11 \times 64 - 3 \times 22^2 \times \frac{{\cdot}7854)}{2}$		2	1,072
Arching of side arches	2	$18 \times 3{\cdot}14$	$0{\cdot}5 \times 19$	2	2,149
Spandrills of ditto	2	10	$9 \times 0{\cdot}5$	19	720
Steps in rear of Bridge, 1st & 2nd	2	60	$3\frac{1}{2}$	3	1,260
Next 3 ...	2	59	6+4	$0{\cdot}5 \times 3$	1,770
" 3 ...	2	58	6+4	$0{\cdot}5 \times 3$	1,740
" 3 ...	2	56	6+4	$0{\cdot}5 \times 3$	1,680
" 3 ...	2	53	6+4	$0{\cdot}5 \times 3$	1,609
" 3 ...	2	48	7+5	$0{\cdot}5 \times 3$	1,728
" 3 ...	2	41	4+2	$0{\cdot}5 \times 3$	738
Remainder ...	2	32	5+2	$0{\cdot}5 \times 3$	672
Wall under top	2	28	3	$1\frac{1}{2}$	252
Do. ...	2	28	2	$3\frac{1}{2}$	392
Parapets of curved wings ...	4	$\frac{24 \times 3{\cdot}14}{4}$	3	$1\frac{1}{2}$	678
Heads of Lock walls ...	8	$\frac{3{\cdot}1416}{2} \times 8\frac{1}{2} \times 3$		$1\frac{1}{2}$	836
Ditto Piers	16	$\frac{3{\cdot}1416}{2} \times 4 \times 3$		$1\frac{1}{2}$	452
Crossing lock channel	4	16	3	$1\frac{1}{2}$	288
Crossing arches	12	18	3	$1\frac{1}{2}$	972
Sides of lock chamber	4	132	3	$1\frac{1}{2}$	2,376
Sides of bason, front of bridge ...	2	12	3	$1\frac{1}{2}$	108
Rear of bridge, round curve ...	2	106	3	$1\frac{1}{2}$	954
Front	2	22	3	$1\frac{1}{2}$	198
Dwarf pillars	8	2	2	3	96
Total Masonry...	...	...	...	...	2,85,964
Excavation.					
First	1	250	75	21·5	403,125
Second	1	200	25	16·5	82,500
Total ...	...	...	...	...	485,625
Cut Stone-work.					
Seat for lock gates	8	24·5	2	2	784
Heads of sluice pier	9	13	2	2	468
Coping of all parapets, see length of parapets in masonry ...	1	1,160	2	0·5	1,160
String course of ditto	1	1,160	1	0·5	580
String course of bridge piers and abutments	6	40	1	0·5	120
Outer faces of arches	16	31·5	2	2	2,016
Total Cut Stone-work ...	...	...	..	...	5,128

	No.	B.	D.	L.	Total.
Metalling.					
1st Bridge	1	58	16	0·5	464
2nd do.	1	13	16	0·5	104
Sides of lock chambers	2	150	32	0·5	4,800
Total	...	...	...	...	5,368
Gates.					
Lock gates...	8	0·75	10	26	1,560
Sluice gates	12	0·17	2·5	8	41
Total	...	...	...	...	1,601

ABSTRACT.

		Rs.
485,625	Excavation, at Rs. 6 per 1,000	2,913
275,800	Masonry, at Rs. 15 per 100	41,370
8,548	Arching, at Rs. 25	2,139
5,128	Cut stone-work, extra charge, Rs. 30	1,538
5,368	Metalling, at Rs. 6	322
1,601	Gates, including apparatus, at Rs. 5	8,005
	10 Drum sluices, at Rs. 100	1,000
	Contingencies at 5 per cent.	2,864
	Total cost of Eastern Lock Channel Head, ... Rs.	60,151

No. 5, Tootla Syphons.

	No.	L.	B.	D.	Total.
Excavation	1	182	107	24	4,67,376
Masonry.					
Foundation blocks, 1st	50	(13 × 7—10 × 4)		12	30,600
2nd	8	14 × 7—11 × 4		12	5,184
3rd	4	15 × 7—12 × 4		12	2,736
4th	8	$9\frac{1}{2}$ × 9—6 × $6\frac{1}{2}$		12	4,464
Flooring—Body of the work under all, over blocks... ...	1	138	108	2	29,808
Over outer blocks, up and down stream ...	2	108	7	2	3,024
Over wing blocks ...	4	31·5	$\frac{17+7}{2}$	2	3,024
Steps and supporting walls—Whole blocks, triangular over floor level	2	106	26 × 0·5	13·5	37,106
Add half back walls ...	2	106	2	13·5	5,721
Total ...	...	......	......	......	1,21,670
Deduct triangular prism between side walls	2	98	16·5 × 0·5	6·5	10,510
Also reduced thickness of wing wall, say	4	12	1	13·5	648
(Leaving segment of arch to cover cost of turning.)					
Total Deductions ...	...	......	......	......	11,158
					1,10,512
Abutment walls of aqueduct ...	2	123	5	5	6,150
Piers of aqueduct	9	123	4	5	22,140
Starlings to do.	18	4 × 4	0·78 × 0·5	5	565
Abutment walls of road bridge ...	4	15	4·5	8	2,160
Do. behind spandrills	4	15	1·5	5	450
Piers of road bridge	18	15	3	8	6,480
Starlings to do.	18	3 × 3	0·78 × 0·5	8	509
Caps to do.	18	3 × 3	$\frac{\cdot 7854}{2}$	0·16 × 1	21
Wing walls above steps	4	28	4·5	(18 + 11)0·5	7,308
Do. curved portion above steps	4	8	3	(11 + 7)0·5	864
Do. upper parts	4	22	3	8	2,208
Aqueduct floor	1	106	92	3	29,256
Walls, straight part ...	2	106	4	10	8,480
Splays	4	25	12 × 0·33	12	4,800
Steps beyond ...	4	13·5	(17 + 11·5) × 0·5	12	9,234
Total ...	...	......	......	......	2,11,137
Deduct hollow under arch taken triangular	4	13·5	9 × 0·5	5·5	1,336
Total ...	...	...		......	2,09,801

	No.	L.	B.	D.	Total.
Brought forward ...	...	......	......	......	2,09,801
Arching	20	$(10^2-7^2)\times0{\cdot}78\times0{\cdot}25\times15$			6,008
Spandrills (solid)	20	$(10\times5-10^2\times0{\cdot}78\times0{\cdot}5)\times15$			3,219
Parapets—Over curves of wing walls	4	22	1·5	3	396
" Straight part ...	4	20	1·5	3	360
" Bridges	4	99	1·5	3	1,782
" Curves beyond bridge	4	27	1·5	3	486
Total Masonry ...	...	......	......	......	2,22,052
Concrete under all	1	124	97	3	36,084
Extra cost stone beams supporting aqueduct, and in flooring under bridge	2	93	92	2	34,224
*Iron Work.**					
Longitudinal pieces	40	84	0·17	0·04	23·33
Vertical do.	10 × 92	9·5	0·78	·06 × ·06	26·60
Nuts	10 × 92	0·04	0·08	0·08	0·27
Total ...	...	......	......	......	60·20
Metalling over roadways	2	175	16	0·5	2,800
Dry Stone-work	1	120	25	3 × 0·5	9,000
	1	100	12	3 × 0·5	10,800
Total ...	...	......	......	......	10,800
Extra cost of Cut Stone-work.					
Coping of parapets	...	804	2	0·5	804
String course—Outside bridge parapets... ...	2	93	1	0·5	93
Tops of piers and abutments ...	18	34·5	1	0·5	310·5
Wing walls ...	4	35	1	0·5	70
Total ...	...	...	...	...	1,277·5

* The greatest pressure on the top of the openings will amount to 17 feet of water on the lower surface of the covering of the openings, that is on ⅔rd of the flooring of the aqueduct, equal to, say 12 feet on the whole floor. Of this six feet is more than met by the weight of the 3 feet of masonry, and, if the canal be empty at the time of the flood passing, the rest must be met by iron ties, holding down the stone beams to the piers. This balance of pressure is equal in each running foot of opening to $6\times9\times62{\cdot}5=3{,}375$lbs., and if one tie be placed on each side at every two running feet, each will have to support this pressure, which at 5 tons to the square inch will require a section of 0·3 of a square inch nearly. The ¾ of inch (=·0625 foot) bolt gives 0·44 of a square inch section.

ABSTRACT.

		Rs.
467,376	Cubic feet of excavation, at Rs. 6	2,804
216,044	ditto of masonry, at Rs. 15	32,406
70	Sinking blocks, at Rs. 50	3,500
70	Curbs for do., at Rs. 25...	1,750
36,084	Concrete, at Rs. 12	4,330
34,224	Extra cost of stone beams, at Rs. 10 per 100	3,422
60·20	Cubic feet or 258·66 cwt. iron work, at Rs. 20...	5,173
10,800	Ditto dry stone-work, at Rs. 6 per 100	648
2,800	Ditto metalling, at Rs. 6	168
1,277·5	Cut stone-work (extra cost), at Rs. 30	383
	Contingencies, at 5 per cent.	2,729
	Total cost, Rs.	57,313
	Or for five Syphon Drains ... ... "	2,86,565

If the soil should prove favourable, the expense may be reduced by the following items:—

		Rs.
Masonry in blocks	Cubic feet 42,984	
Less extra thickness of floor	" 14,904	
	Cubic feet 28,080 at Rs. 15	4,212
Sinking blocks...		3,500
Curbs to do.		1,750
Concrete		4,330
Share of contingencies		689
	Total...	14,481
Making the cost for each Syphon of 10 spans 6 × 5, ...	...Rs.	42,838
Or for the five	"	2,14,190

Second Plan.

To cross the Tootla by Inlet and Escape would require the excavation of channels to carry off the waters from the canal towards the Soane. Three of the escapes should be in the 8th mile of the canal line. The Tootla near Tilothoo is a large Nala, and becomes so about 1½ miles from this part of the canal line. The level of the bed of the former is 334·10 feet above the datum, and of the latter 339·75. Giving the escapes a drop of 2 feet on leaving the canal, the channel would have a fall of about 2½ feet in the mile, which would answer very well for an escape only occasionally carrying a large body of water. The excavation would be rather heavy. Even allowing for the partial adoption of existing Nalas, it cannot be reckoned at a less average depth than 8 feet.

The fourth escape would be at the 9th mile, where it would be necessary to excavate a channel of about 5 miles. The fifth would be near the 10th mile, when the drainage would fall into the escape channel above the first bifurcation of the canal, at the end of about ½ a mile.

It would be necessary therefore to provide three channels of ½ a mile each to carry 1,500 cubic feet a second, uniting into one of one mile long of 4,500 cubic feet per second; at the 9th mile one of 1,500 cubic feet, a second for 5 miles,

and at the 10th mile one of half a mile. These discharges would require width at bottom of 50 and 110 feet respectively, with depths of $6\frac{1}{4}$ and 8. On the whole there will be 7 miles of the smaller size and one of the larger, thus the excavation would be:—

$$7 \times 5{,}280 \times 8 \times (50+8+4) = 18{,}332{,}160$$
$$1 \times 5{,}280 \times 8 \times (110+8+4) = 5{,}153{,}280$$

Total... 23,485,440 cubic feet, at $2\frac{1}{2}$ Rs. per 1,000 ...	58,713
Contingencies at 5 per cent.... ...	2,936
	61,649

Land for these channels	1 mile	at 660 feet width =	128 beegahs.	
	7 miles	330 ditto ...	448 "	
		Total	576 beegahs.	
which at 6 Rs. a beegah will come to Rs. ...				3,456
5 Inlets of 3 spans with drop to canal bed, at Rs. 8,552* each			42,760	
5 Escapes, 6 " each at Rs. 16,785†			83,925	
1 Bridge of 4 " of 33 feet near Tilothoo‡...			23,000	
1 Do. of 2 " near Hurna Cheetee‡			15,500	1,65,185
			Total cost, Rs. ...	2,30,290

This is if block-sinking is necessary in the foundations: if not, the amount will be:—

Excavation and land as before	65,105
5 Inlets*	21,455
5 Escapes†	41,525
1 Bridge, 4 spans of 33 feet...‡	17,000
1 Do. 2 " " ...‡	11,700
Total cost, Rs. ...	1,56,785

Third Plan.

If the Escape Channels were used with the Syphon Drains, a better head of water, and consequently a more rapid discharge, would be obtained by the lowering of the surface of the drainage water west of the Canal. It would thus be possible to reduce the water-way, giving only 7 instead of 10 openings to each drain. This change would admit of a reduction of masonry to the extent of 48,300 cubic feet in the case of under-sunk foundations being required, and 45,036 cubic feet otherwise. Besides this there would be a reduction of masonry in lowering the tail steps to the level of the bed of the excavated channel, making the reduction in all say 54,000 cubic feet in the one case, and 51,000 in the other. We might also dispense with the iron-work, which would no longer be required under the reduced pressure

* See detailed Estimate No. 8.
† See detailed Estimate No. 7.
‡ See detailed Estimate No. 13.

which would be the consequence of this arrangement; and also with the stone beams in the floor placed there for securing the iron-work.

Thus the total reduction would be :—

	With under-sunk Foundations.	With ordinary Foundations.
	Rs.	Rs.
Masonry at Rs. 15 per 100	8,200	7,650
Iron-work	5,173	5,173
Extra cost of half the stone beams	1,711	1,711
Contingencies	754	726
Total reduction ...	15,838	15,260
Leaving the cost of each drain ...	41,475	27,578
Hence the total for 5 syphons will be	2,07,375	1,37,890
Excavation and land	65,105	65,105
2 Bridges as before	38,500	28,700
Total	3,10,980	2,31,695

This plan, though more expensive, is more satisfactory than either of the others; and I have therefore included the sum of Rs. 3,10,980 in the general Estimate.

No. 6, Dam on the Kao.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation Blocks	10	(15·75 × 7—12·75 × 4)		17	10,030
Ditto	44	(13 × 7—10 × 4)		17	38,148
Ditto	7	(12 × 7—9 × 4)		17	5,712
Ditto	8	(10·5 × 7—7·5 × 4)		17	5,916
Ditto	2	(9 × 7—6 × 4)		17	1,326
Ditto Trapezoidal ...	2	$\left(\frac{10 \times 18}{2} - \frac{6 \times 11}{2}\right)$		17	1,938
Ditto	2	$\left(\frac{9 \times 11}{2} - \frac{6\frac{1}{2} \times 5}{2}\right)$		17	476
Flooring taken under piers, upper bridge	1	75	21	2	3,150
Main quadrangle	1	110	89	2	19,580
Lower bridge and below do.	1	88	75	2	13,200
Segmental portion ...	1	44 × 7	0·66	2	410
Total ...	...	...	...	...	99,886
Deduct 4 quadrants in large quadrangle	4	32 × 32	0·785 × 0·25	2	1,608
Rectangles...	2	11	8	2	352
Total deductions...	...	...	...	...	1,960
Masonry carried forward...	...	...	...	...	97,926
Wing Walls, upper—					
1st including as far as floor of blocks	2	3·14+3	29 × 6	7	2,551
2nd	2	3·14+3	29·5 × 5	4	1,236
3rd	2	3·14+3	30 × 4	5	1,256
4th	2	3·14+3	30·5 × 3	7	1,341
Ditto Semi-circle—					
1st	4	3·14	29 × 6	7	15,306
2nd...	4	3·14	29·5 × 5	4	7,414
3rd	4	3·14	30 × 4	5	7,538
4th...	4	3·14	30·5 × 3	7	8,048
Ditto Curve of 60 feet radius					
1st	2	25	6	7	2,100
2nd...	2	25	5	4	1,000
3rd	2	25	4	5	1,000
4th	2	25	3	7	1,050
Lower quadrant radius 27 interior, 37 exterior, length of arc allowing for circular ends, say... ...	2	54	(10 + 6)	0·5 × 5	4,320
2nd...	2	53	(9 + 6)	0·5 × 2	1,590
3rd	2	52	(8 + 5)	0·5 × 2	1,332
4th	2	51	7 + 5	0·5 × 2	1,224
5th	2	50	6 + 4	0·5 × 2	1,000
6th	2	49	5 + 4	0·5 × 2	882
7th	2	48	4 + 3·5	0·5 × 2	720
8th	2	47	3 + 3	0·5 × 2	564
Carried over ...	...	......	......	......	1,59,398

	No.	L.	B.	D.	Total.
Brought forward ...	...	......	......	......	1,59,398
Walls across Canal bed	2	57	7	2	1,596
	2	57	3	$5\frac{1}{4}$	1,795
Abutments—					
1st Portion	4	19	6	7	3,192
2nd...	4	19	5	4	1,520
3rd	4	19	4	5	1,520
4th (behind arch)	4	19	1·5	7	798
Piers, bodies (including groove seats)	10	20	3	14	8,400
Do. Starlings to top of parapet	15	$\frac{\cdot 7854}{2}$	3^2	24	1,272
Do. Steps	5	1	3	21	315
Do. Do.	5	$\frac{21}{2}$	3	21	3,307
Arching	12	19	$\frac{13^2-10^2}{2}$	0·7854	6,178
Spandrills (solid)	12	$13^2\ (1{\cdot}0-0{\cdot}7854) \times 19 \times \frac{1}{2}$			4,134
Parapets over bridge	4	75	1·5	3	1,350
" circular wings ...	4	3·1416	15·5×1·5	3	862
" upper curved wings	2	$\frac{31416}{3}$	31·25 × 1·5	3	294
" Lower ditto ...	2	19	1·5	3	171
Total Masonry...	...	...	...	...	196,102
Concrete.	...	3,150			
Under floors: $1\frac{1}{2}$ flooring as entered above	...	19,580			
	...	13,200			
	...	410			
	...		36,340		
	...	......	1,936		
	1·5	......	34,380	......	51,570
Deduct Blocks	10	15·75	7	3	3,307
Ditto	8	13	7	3	2,184
Ditto	6	12	7	3	1,512
Ditto	2	10·5	7	3	441
Projecting portions of blocks under curtains and wings ...	2	10	2	3	120
Total deductions...	...	.....	......	......	7,664
Total Concrete...	...	......	......	......	43,906
Excavation.					
In Kao	...	300	$\frac{40}{2}$	18	108,000
In Canal	...	300	$\frac{12}{2}$	11	19,800
Below Canal in quadrangle ...	...	89	110	10	97,900
Total Excavation...	...	......	......	......	2,25,700
Gates with apparatus complete superficial feet	10	11	$10\frac{3}{4}$	......	1,182

	No.	L.	B.	D.	Total.
Dry Stone-work.					
Canal bed ... } banks included...	2	80	30	2·5	12,000
Kao up stream ... } banks included...	1	90	20	2·5	4,500
Do. down do. ... } banks included...	1	90	40	3·0	10,800
Total ...	...	...	...	...	27,300
Metalling.					
First	2	75	16	0·5	1,200
Second	4	20	24	0·5	960
Total ...	...	...	...	...	2,160
Cut Stone-work.					
Coping of all parapets	...	594	2·0	0·5	599
String course under ditto ...	...	594	1·0	0·5	297
Ditto second in wing walls ...	...	256	1·0	0·5	128
Ditto round tops of piers and abutments	24	23·5	1·0	0·5	282
Faces of arches	24	16	1·0	1·5	576
Grooves	24	21	1·0	0·5	252
Total	...	...	...	...	2,129

ABSTRACT.

		Rs.
225,700	Cubic feet of Excavation, at Rs. 6 per 1,000	1,354
189,924	Ditto of Masonry, at Rs. 15 per 100	28,488
6,178	Ditto Arching, at Rs. 20 per 100...	1,236
43,906	Ditto Concrete, at Rs. 12 per 100	5,269
75	Blocks, curb frames, at Rs. 25 each	1,875
75	Ditto sinking, at Rs. 50 each...	3,750
2,129	Cubic feet of cut stone-work, at Rs. 30 per 100	639
1,182	Superficial feet of gates, with apparatus, at Rs. 3 per foot ...	3,546
27,300	Cubic feet dry stone work, at Rs. 6 per 100	1,638
2,160	Metalling road-ways, at Rs. 6 per 100...	130
	Contingencies, at 5 per cent. ...	2,396
	Grand Total, Co.'s Rs. ...	50,321

If however the soil should prove good, as appears probable, there will be a reduction of the following items :—

	Rs.
Three-fourths of the masonry in blocks or 47,662 cubic feet, at Rs. 15 ...	7,149
The Concrete	5,269
The sinking of the blocks	3,750
The Curb frames	1,875
Share of Contingencies	902
In all Rs. ...	18,943
Leaving the cost of the Dam in that case, Rs. ...	31,378
The full amount however is estimated for, or Rs. ...	50,321

No. 7, Escapes.

A. Wing walls and abutments with two semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation wells under semi-circular wings	8	(8^2-5^2)	0·7,854	12	2,940
Blocks	2	$(8\frac{3}{4}\times7)-(5\frac{3}{4}-4)$		12	1,428
Ditto	2	$(9\frac{1}{2}\times7)-(6\frac{1}{2}\times4)$		10	810
Ditto	5	$(12\times7)-(9\times4)$		12	2,880
Ditto	9	$(12\times7)-(9\times4)$		10	4,320
Front semi-circular wing walls ...	2	$\frac{3{\cdot}1{,}416}{2}\times13\frac{1}{2}\times3$		$8\frac{1}{2}$	1,081
Rear quadrants	2	$\frac{3{\cdot}1{,}416}{4}\times13\frac{1}{2}\times3$		10	636
Ditto	2	$\frac{3{\cdot}1{,}416}{4}\times11\frac{1}{2}\times1$		$5\frac{1}{2}$	99
				Mean.	
Front straight portion of wall ...	2	$4\frac{1}{2}$	3	10	270
Rear ditto ditto ...	2	41	3	10	2,460
Ditto ditto ditto ...	2	10	3	9	540
Ditto ditto ditto ...	2	3	3	8	144
Ditto ditto ditto ...	2	41	1	$5\frac{1}{2}$	451
Ditto ditto ditto ...	2	10	1	$4\frac{1}{2}$	90
Ditto ditto ditto ...	2	3	1	$3\frac{1}{2}$	21
Ditto ditto ditto steps near bridge	2	$\frac{7+2}{2}$	3	$2\frac{1}{2}$	67
Abutment blocks	4	3	6	10	720
Ditto walls	2	16	4	6	768
Ditto ditto	2	16	2	4	256
Skew backs of arches	2	$\frac{19}{2}$	1·2	0·9	20
Two semi-arches	1	$11\frac{2}{3}$	19	$1\frac{1}{2}$	332
Spandrills, solid	1	$12{\cdot}4\times31-21{\cdot}44$		19	323
Dwarf pillars	4	$2\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{1}{2}$	87
Parapets	4	5	$1\frac{1}{2}$	$3\frac{1}{2}$	105
Flooring over blocks	8	$8^2\times$	0·7,854	2	804
Ditto ditto	2	$8\frac{3}{4}$	7	2	245
Ditto ditto	2	$9\frac{1}{2}$	7	2	266
Ditto ditto	14	12	7	2	2,352
Ditto under semi-arches	2	64	4	2	1,024
Ditto intervals of blocks in curtain-wall	8	3	2	2	96
Ditto ditto ditto	5	7	$\frac{1}{2}$	2	35
Ditto ditto ditto	7	7	1	2	98
Total Masonry ...	...	...	...	...	25,768
Excavation.					
Straight portion...	2	102	11	12	26,928
Curved wings	2	36	8	10	5,760
Tail ditto	2	18	8	12	3,456
Total Excavation ...	...	...	...	...	36,144

	No.	L.	B.	D.	Total.
Sluice shutters	2	$\frac{11}{2}$	...	7	77
Dry stone-work	2	20	6	3	720
	2	15	15	2	900
	...	...	...	...	1,620
Metalling	2	16	10	0·5	160
Cut Stone-work.					
Coping of parapets	2	10	2	0·5	20
Ditto of pillars	4	25	2·5	0·5	12·5
String course of parapets ...	2	10	1	0·5	10
Ditto of pillars	4	8	1	0·5	16
Face of arch	2	11	1	1·5	33
Front grooves	2	6·5	1	0·5	6·5
Rear ditto	2	11	1	0·5	11
Total ...	...	...	...	...	109

ABSTRACT.

		Rs.
36,144	Cubic feet of Excavation, at Rs. 5 per 1,000...	181
25,768	Ditto Masonry, at Rs. 15 per 100	3,865
16	Blocks curb frames, at Rs. 25 each	400
10	Ditto at Rs. 15 each	150
26	Sinking blocks, 15 feet, at Rs. 50 each	1,300
77	Square feet sluice shutters, with apparatus complete, say at Rs. 3	231
1,620	Dry stone-work, with piling, at Rs. 8 per 100	130
109	Cubic feet cut-stone work, extra charge, at Rs. 30	33
160	Cubic feet of metalling, at Rs. 6 per 100	10
	Contingencies, at 5 per cent	315
	Total Rs. ...	6,615

If the soil were such as to render block sinking unnecessary, there would be a saving of nearly ¾ of the masonry in blocks, or say 9,000 cubic feet of masonry, at Rs. 15 per 100	1,350
Curb frames	550
Sinking blocks	1,300
Contingencies, at 5 per cent.	160
Total Rs. ...	3,360
Leaving as the cost of two abutments and semi-arches of the Escape, Rs. ...	3,255

B. Pier with two semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	2	11 × 7 − 8 × 4		10	900
Ditto	1	11 × 7 − 8 × 4		11	495
Ditto	1	11 × 7 − 8 × 4		12	540
Ditto	1	$12\frac{1}{2} \times 7 - 9\frac{1}{2} \times 4$		10	495
Ditto	1	$12\frac{1}{2} \times 7 - 9\frac{1}{2} \times 4$		12	594
Flooring over all	1	78	13	2	2,028
Total ...	...	...	...	...	5,052
Pier under bridge to spring ...	1	19	3	6	342
Upper semi-circular end ...	1	$\frac{\cdot 7{,}854}{2}$	3^2	6·5	23
Straight portion as far as groove	1	2	3	6·5	39
From that to bridge	1	$5\frac{1}{2}$	3	$\frac{9+11}{2}$	165
Flat portion below bridge, curved ends taken square ...	1	3	3	$18\frac{1}{2}$	166
First step from top	1	1	3	10	30
Steps above slope in floor ...	1	10	3	$\frac{7+10}{2}$	255
Ditto below ditto	1	13	3	$\frac{7+\frac{1}{2}}{2}$	146
Two semi-arches as in Part A ...	1	$11\frac{1}{3}$	19	$1\frac{1}{2}$	332
Skew backs	2	$\frac{19}{2}$	1·2	0·9	20
Spandrill, solid	1	(12·4 × 3·1 − 21·44)		19	323
Parapets	2	10	$1\frac{1}{2}$	$3\frac{1}{2}$	105
Total Masonry ...	...	...	...	...	6,998
Excavation.					
In excess of what is calculated in the escape channel	200	6	7	...	8,400
And below level of floor	102	13	5	...	6,630
Total Excavation ...	...	...	...	...	15,030
Dry stone-work	1	35	13	3	1,365
Sluice shutters	2	$\frac{11}{2}$	...	7	77
Metalling road-way	1	13	16	$\frac{1}{2}$	104
Cut Stone-work.					
As in A, omitting the pillars ...	...	......	......	......	80

ABSTRACT.

		Rs.
15,030	Cubic feet of Excavation, at Rs. 5 per 1,000	75
6,998	Ditto Masonry, at Rs. 15 per 100	1,050
6	Blocks, sinking, at Rs. 50 each	300
6	Ditto, Curbs, at Rs. 25 each	150
80	Cubic feet cut stone-work, at Rs. 30 per 100	24
1,365	Cubic feet of Dry stone-work, with piles, at Rs. 8 per 100 ...	109
104	Ditto Metalling road-way, at Rs. 6 per 100	6
753	Ditto Sluice shutters, apparatus included, at Rs. 3 per foot,	221
	Contingencies	97
	Total Rs. ...	2,034

If the soil be such as not to require block-sinking, deduct as follows :—

		Rs.
3,500	Cubic feet of masonry in blocks, at Rs. 15 per 100	525
	Curb frames	150
	Sinking blocks	300
	Contingencies, at 5 per cent.	49
	Total Rs. ...	1,024
	Leaving the cost of the pier and two semi-spans ... ...Rs.	1,010

GENERAL ABSTRACT.

With Block-sinking.	Add.	Total.
Escape of 1 opening as per A	...	6,615
2 openings, adding as per B...	2,034	8,649
3 ditto	2,034	10,683
4 ditto	2,034	12,717
5 ditto	2,034	14,751
6 ditto	2,034	16,785
8 ditto	2,034	18,819
Without Block-sinking.		
1 opening	...	3,255
2 ditto	1,010	4,265
3 ditto	1,010	5,275
4 ditto	1,010	6,285
5 ditto	1,010	7,295
6 ditto	1,010	8,305
8 ditto	1,010	9,315

As an average, the cost will be taken as follows in the general estimate for the Canals of the Ist, IInd and IIIrd Classes.

	Average of the two.	Amount used.
Escape of 1 opening	4,935	5,000
2 ditto	6,457	6,000
3 ditto	7,979	8,000
4 ditto	9,501	9,500
5 ditto	11,023	11,000
6 ditto	12,545	12,500
8 ditto	14,067	14,000

For the other classes of Canals the cost of Escapes will be taken as follows :—

	Cost of Escapes of			
	10 feet opening.	20 feet opening.	30 feet opening.	40 feet opening.
Classes IV. and V.	4,000	5,250	6,500	7,750
Class VI.	3,000	4,000	5,000	6,000
Class VII.	2,500	3,250	4,000	......
Class VIII.	2,000	2,600	......	......
Class IX.	1,500	2,000	......	......
Class X.	1,000	......	......	......

A. *Wing walls, abutments, and two semi-arches.*

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	4	$(8·5 \times 7)-(5·5 \times 4)$		12	1,800
Ditto	4	$(10 \times 7-7 \times 4)$		12	2,016
Ditto	10	$(13 \times 7-10 \times 4)$		12	6,120
Flooring over ditto	4	8·5	7	2	476
Ditto	4	10	7	2	560
Ditto	10	13	7	2	1,820
Flooring of inlet	2	27·5	5	2	550
Steps	2	18	5	5	900
					14,242
Deduct hollow under steps taken triangular	2	9	5	2	180
	...	...	...	...	14,062
Part wall at back of ditto ...	2	5	2	10	200
Abutment walls between counter-forts	2	13	4	9	936
Ditto ditto ditto ...	2	13	2·5	1	65
Ditto ditto ditto ...	2	13	1·5	2	78
Ditto ditto ditto ...	2	13	·5	3·5	45
Counterforts	8	7	2	9	1,008
Ditto	8	5·5	2	6·5	572
Wing walls straight portion ...	2	24	4	9	1,728
Ditto ditto ...	2	24	3	6·5	936
Ditto curved upper ...	2	$\frac{16·5 \times 3·1416}{3}$	3	15	1,555
Ditto lower	2	10	4	9	720
Ditto ditto	2	10	3	3·5	210
Ditto ditto	2	10	3	5·5	330
Ditto ditto	2	12	2	1·5	72
Two semi-arches	1	$\frac{11·5 \times 3·1416}{2}$	19	1·5	495
Spandrills, solid	1	$\frac{13^2 \times (1-0·7854)}{2}$		19	374
Parapets	4	5	1·5	3·5	105
Dwarf pillars	4	2·5	2·5	3·5	87
Total Masonry ...	...	...	...	...	23,278
Cut Stone-work.					
Coping to parapets	2	14	2·0	0·5	28
String course below ditto ...	2	14	1·0	0·5	14
Ditto in wing walls and abutments	2	30	1·0	0·5	30
Faces of arch	2	14	1·0	1·5	42
Total ...	...	...	...	...	114

	No.	L.	B.	D.	Total.
Dry Stone-work.					
Below Inlet	2	13	5	3	390
Ditto front of wing	2	$18^2 \times \frac{1-0{\cdot}7854}{4}$		2	68
Above Inlet	2	10	5	2	200
Ditto front of wings	2	12	4	1·5	144
Total Dry Stone-work ...					802
Excavation	2	75	12	16	28,800
Metalling road-way	2	8	16	·5	128

ABSTRACT.

		Rs.
28,800	Cubic feet excavation, at Rs. 4 per 1,000 cubic feet	115
23,278	" masonry, at Rs. 15 per 100 cubic feet	3,492
18	Curb frames, at Rs. 25 each	450
18	Sinking blocks, at Rs. 50 each...	900
114	Cubic feet cut stone-work, at Rs. 30 per 100 cubic feet	34
802	" dry stone-work, at Rs. 6 per 100 cubic feet	48
128	" metalling road-way, at Rs. 6 per 100 cubic feet... ...	8
	Contingencies, at 5 per cent.	251
	Total one inlet of 10 feet drop	5,298

If block sinking-should not be necessary, there will be the following reduction:

	Rs.
About three-fourths, or say 7,500 cubic feet of masonry in blocks, at Rs. 15 per 100 cubic feet	1,125
Curb frames	450
Sinking blocks	900
Contingencies at 5 per cent.	124
Total Rs. ...	2,599

Leaving the cost of the Wing walls and two semi-spans ...Rs. 2,699

B. Pier with two semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	2	((10·5 × 7) − (7·5 × 4)		12	1,044
Ditto	3	(12 × 7) − (9 × 4)		12	1,728
Flooring over all	1	36·5	13	2	897
Steps	1	18	13	5	1,170
Wall behind ditto...	1	13	2	10	260
					5,099
Deduct hollow taken triangular ...	1	13	9	2	234
					4,865
Pier	1	19	9	3	513
Two semi-arches	1	$\frac{11·5 \times 3·1416}{2}$	19	1·5	1,026
Spandrills, solid	1	$13^2 \times$	$\frac{1-0·7854}{2}$	19	342
Starlings	2	$\frac{3^2 \times 0·7854}{2}$	...	20	140
Parapets	2	13	1·5	3·5	136
Total Masonry... ...	...	...	...	...	7,022
Cut Stone-work.					
Coping of parapets	2	13	2·0	0·5	26
String course below ditto ...	2	13	1·0	0·5	13
Ditto ditto at head of pier ...	2	23·5	1·0	0·5	23
Faces of arch	2	14	1·0	1·5	42
Total ...	...	...	...	..	104
Dry Stone-work.					
Below Inlet	1	13	13	3	507
Above Ditto	1	13	8	2	208
					715
Excavation	1	50	13	16	10,400
Metalling	1	13	16	·5	104

ABSTRACT B.

10,400	Cubic feet excavation, at Rs. 4 per 1,000 cubic feet	42
7,022	" masonry, at Rs. 15 per 100 cubic feet	1,053
5	Curb frames, at Rs. 25 each	125
5	Sinking blocks, at Rs. 50 each	250
104	Cubic feet cut stone-work, at Rs. 30 per 100 cubic feet ...	31
715	" dry stone-work, at Rs. 6 per 100 cubic feet	43
104	" metalling, at Rs. 6 per 100 cubic feet	6
	Contingencies, at Rs. 5 per cent.	77
	Total for one pier with semi-arches ... ... Rs.	1,627

The following will be the deductions if block-sinking is not wanted:—	Rs.
⅕th of masonry in blocks, or say 2,772 cubic feet, at Rs. 15	416
Curb frames	125
Sinking blocks	250
Contingencies at 5 per cent.	40
Total Rs. ...	831
Leaving the cost of the pier and two semi-spans ... ... Rs.	796

GENERAL ABSTRACT.

	With Blocks.	Without Blocks.	Mean.	Amount used.
One opening	5,298	2,699	3,998	4,000
Add	1,627	796		
Two openings	6,925	3,495	5,210	5,200
Add again...	1,627	796		
Three openings	8,552	4,291	6,421	6,500

The amounts in the last column are taken in the General Estimate.

No Inlets of this description are required on the smaller branches of the Canals.

A. *Wing walls, abutments, and two semi-arches.*

	No.	L.	B.	D.	Total.
Masonry.					
Wells under wing walls	18	(8^2-5^2)	0·7854	9·5	5,278
Foundation blocks	2	$(7+4)$	$(7-4)$	9·5	627
Ditto	4	$(10\frac{1}{2}\times7-7\frac{1}{2}\times4)$		9·5	1,653
Flooring over blocks	18	8^2	0·7854	1·5	1,337
Ditto ditto	2	7	7	1·5	147
Ditto ditto	4	10·5	7	1·5	441
Ditto interval between blocks ...	2	8	4	1·5	96
Wing walls, front...	2	$22\frac{1}{2}\times\frac{3·1416}{2}$	8	3	1,576
Ditto rear	2	$15\times3·1416$	8	3	2,265
Steps at flanks of bridge ...	4	$\frac{5}{2}$	3	3	90
Abutments...	2	19	4	6	912
Backing of arch	2	19	1·8	4	273
Skewbacks...	2	19	1·2	$\frac{0·9}{2}$	19
Arching	1	11·5	19	1·5	328
Spandrills, solid	1	$(13\times3·1-22·4)$		19	340
Parapet	4	5	1·5	3·5	105
Terminal blocks of ditto ...	4	3	2	3·5	84
Total Masonry ...	...	...	...	...	5,658
Dry Stone-work.					
Above Inlet	2	10	11	2	440
Below ditto	2	15	14	2	840
Total ...	...	...	...	...	1,280
Excavation.					
First	2	22	11	7	3,388
Second	2	80	8	7	8,960
Total ...	...	...	...	...	12,348
Cut Stone-work.					
Coping of parapets	2	15	2·0	0·5	30
String course below ditto ...	2	11·5	1·0	0·5	12
Ditto round abutments	2	19	1·0	0·5	19
Ditto in front wing walls ...	2	46	1·0	0·5	46
Ditto in rear ditto	2	19	1·0	0·5	19
Faces of arch	2	12	1·0	1·5	36
Total ...	...	...	...	...	162

ABSTRACT.

		Rs.
12,348	Cubic feet excavation, at Rs. 4 per 1,000	49
15,658	" masonry, at Rs. 15 per 100...	2,349
18	Curbs for wells, at Rs. 15 each...	270
6	Ditto for blocks, at Rs. 25 each	150
24	Sinking blocks and wells, at Rs. 30	720
1,280	Cubic feet dry-stone work, at Rs. 6 per 100	77
162	" of cut-stone work at Rs. 30 extra charge	49
	Contingencies at 5 per cent.	182
	Inlet, or a level with one opening, total Rs. ...	3,846

If the block-sinking should not be required, the following reductions may be made:—

	Rs.
⅘ths of this masonry in blocks, or say 5,000 cubic feet, at Rs. 15	750
Curbs for blocks and wells	420
Sinking ditto	720
Contingencies at 5 per cent.	95
Total Rs. ...	1,985
Leaving the cost of the two Abutments and semi-spans Rs. ...	1,861

B. Pier and two half Spans.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation Blocks	1	(7 + 4) × (7 − 4)		9·5	313
Ditto	2	(12·5 + 7 − 9·5 × 4)		9·5	940
Flooring over all	1	22	13	1·5	429
Pier	1	19	3	6	432
Starlings to ditto...	2	3 × 3	$\frac{0·7854}{2}$	7	49
Skew	2	19	1·2	$\frac{0·9}{2}$	20
Two semi-arches	1	11·5	19	1·5	328
Spandrills	1	(13 + 3·1 − 22·4)		19	340
Parapets	2	13	1·5	3·5	136
Total Masonry ...	...	...	...	...	2,897
Cut Stone-work.					
Coping of parapets	2	13	2·0	0·5	26
String course below ditto ...	2	13	1·0	0·5	13
Do. round abutments and starlings	2	24	1·0	0·5	24
Faces of arch	2	12	1·0	1·5	36
Total ...	...	...	...	...	99
Dry Stone-Work.					
Above Inlet	1	10	13	3	390
Below ditto	1	15	13	3	585
					975
Excavation	1	50	10	7	3,500

ABSTRACT.

		Rs.
3,500	Cubic feet excavation, at Rs. 4 per 1,000 cubic feet	14
2,897	Ditto masonry, at Rs. 15 per 100 cubic feet	435
3	Curbs for blocks, at Rs. 25 each	75
3	Blocks, sinking, at Rs. 30 each	90
99	Cubic feet of cut-stone work, at Rs. 30 per 100 cubic feet ...	30
975	Ditto dry stone-work, at Rs. 6 per 100 cubic feet	58
	Contingencies at 5 per cent.	35
	Total Rs....	737

If block-sinking be not required, the following may be deducted:—

⅘ths of the masonry in blocks, or say 1,200 cubic feet at Rs. 15 ...	180
Block-sinking	90
Curbs for blocks	75
Contingencies at 5 per cent.	17
Total Rs.... ...	362

Leaving the cost of the pier and two semi spans ... ... Rs. 375

GENERAL ABSTRACT FOR CANALS OF THE Ist, IInd AND IIIrd CLASSES.

	With Block-sinking.	Without Block-sinking.	Average.	Cost used.
One opening	3,846	1,861	2,853	3,000
Add	737	375		
Two openings	4,583	2,236	3,410	3,500
Add again	737	375		
Three openings	5,320	2,611	3,965	4,000

For the other classes of Canals the following amounts will be used :—

	10 feet opening.	20 feet opening.	30 feet opening,
Classes IV. and V.	2,500	3,000	3,500
Class VI.	2,000	2,500	...
Class VII.	1,800	2,200	...
Class VIII.	1,500	1,800	...
Class IX.	1,000	1,500	...
Class X.	700	...	...

A. Fall of 60 *feet water-way.*

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	8	(14 × 7) − (11 × 4)		11	4,752
Ditto	5	(12·5 × 7) − (9·5 × 4)		11	2,722
Ditto wells	22	(8 + 5) × (8 − 5)0·7854		11	7,413
Upper wing walls	2	18·5 × 3·1416 × 3 × 0·5		12	2,092
Revetment under Fall	1	60	$\frac{4+7}{2}$	18	5,940
Semi-circular side revetments ...	2	31·25 × 3·1416	$\frac{3+6}{2}$	18	15,904
Steps on both sides of Fall ...	2	22	3	1 + 7 × 0·5	528
Walls joining semi-circular sides to bridge	2	9	$\frac{3+6+4+4}{4}$	18	5,508
Steps over ditto	2	12	3	6 × 0·5	216
Raised wall next bridge	2	14	3	6	504
Flooring rectangle in centre ...	1	60	54·66	2	6,559
Ditto 2 semi-circles or (circle)...	1	(27·33 × 2)²0·7854		2	4,693
Ditto 11 feet in front of bridge...	1	0·5(60 + 49)	11	2	1,199
Ditto over blocks of steps below bridge	12	58	7	2	9,744
Back wall supporting steps ...	1	58	5·5	2	638
Ditto ditto...	1	58	4·5	6	1,566
Steps and arch below, equal to rectangular prism	1	58	7	8	3,248
Abutment walls up to level of top of steps	2	14	4	7 × 0·5	392
Piers ditto	3	14	3	7 × 0·5	441
Abutments up to spring	2	22	4	6·5	1,144
Piers ditto	3	22	3	6·5	1,287
Backing over abutments	2	19	2	7	532
Arching	4	5·75 × 3·1416	19	1·5	1,959
Spandrills	4	(13 × 7 − 39·27)	...	19	3,931
Parapets, upper curves	2	12	1·5	3	108
Ditto over bridge	2	49	1·5	3	441
Ditto lower curves	2	15·75 × 3·1,416	1·5	3	445
Dwarf pillars	4	2	2	3	48
Lower wing wall	2	16·25 × 3·14160·5 × 2·5		16·5	810
Ditto	2	16 × 3·14160·5 × 2		6·5	653
Steps beyond bridge, foundation equal to	2	28	5·8	8	2,464
Ditto superstructure ditto ...	2	28	$\frac{9\cdot5+2}{2}$	7 × 0·5	1,127
Total Masonry ...	...	......	......	......	89,008
Cut Stone-work.					
Sill of Fall	1	60	3	1	180
Sides of ditto	2	3	9·5	4	36
Coping of parapets	...	180	2·0	0·5	180
Carried over	...	......	......	......	396

	No.	B.	D.	L.	Total.
Brought forward ...	...	......	......	......	396
String course below parapets ...	...	180	1·0	0·5	90
Ditto round half piers	8	23	1·0	0·5	92
Faces of arches	8	18	1·0	1·5	216
Total cut stone-work ...	...	...	...	...	794
Dry Stone-work.					
Above Fall...	1	70	15	2·5	2,625
Below ditto	1	40	28	2·8	2,800
Sides below steps	2	20	6	6	1,440
Total dry stone-work ...	...	...	...	...	6,865
Concrete.					
See items of flooring 1	...	...	...	...	6,559
2	...	...	...	...	4,693
3	...	...	...	...	1,199
Total Concrete ...	...	...	...	...	12,451
Excavation.					
Over all omitting for channel 50 feet	1	111	67	6	44,622
Bason rectangle	1	67	60	20	80,400
Semicircles...	2	$67^2 \times 0{\cdot}7854 \times 0{\cdot}5$		20	70,513
Total excavation ...	...	...	...	...	1,95,535
Metalling (whole length of work)	1	180	16	0·5	1,440
Planks for closing bridge... ...	20×4	16	0·5	0·125	80

ABSTRACT.

			Rs.
1,95,535	Cubic feet excavation, at Rs. 6 per 1000 cubic feet ...	...	1,173
89,008	Ditto masonry, at Rs. 15 per 100 cubic feet ...	...	13,351
1,959	Ditto arch, at Rs. 20 per 100 cubic feet ...	...	392
12,451	Ditto concrete, at Rs. 12 per 100 cubic feet ...	...	1,494
35	Blocks and wells, sinking, at Rs. 40 each... ...	...	1,400
35	Ditto, curbs, at Rs. 20 each	...	700
884	Cubic feet of cut stone-work at Rs. 30 per 100 cubic feet	...	238
6,865	Cubic feet of dry stone-work with piling, at Rs. 8 per 100		549
80	Cubic feet planks, at Rs. 3 per foot	...	240
1,440	Ditto metalling, at Rs. 6 per 100 cubic feet ...	...	87
	Unwatering	...	2,000
	Contingencies at 5 per cent.	...	1,081
	Total per one Fall 60 feet water-way ...	Rs.	22,705

If the soil be found favourable and such as to enable us to dispense with block-sinking, this cost might be reduced as follows :—

	Rs.
Say half the masonry in blocks or 7,000 cubic feet at Rs. 15 per 100 cubic feet ...	1,050
Curbs for blocks ...	700
Sinking blocks ...	1,400
Unwatering ...	2,000
Contingencies at 5 per cent ...	257
Total ... Rs.	5,407
Leaving the cost of the 60 feet Fall ...	17,298

No. 10, Masonry Falls.

B. Fall of 30 *feet water-way.*

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	6	(12 × 7)—(9 × 4)		10	2,880
Ditto	3	(10·5 × 7—7·5 × 4)		10	1,305
Ditto wells	16	(8 + 5) × (8—5)0·7854		10	4,901
Upper wing walls...	2	13·75 × 3·1416 × 2·5 × 0·5		8	863
Revetment under Fall	1	30	$\frac{2+5}{2}$	13	1,365
Ditto semi-circular at sides ...	2	20·5 × 3·1,416	$\frac{2+4}{2}$	13	5,203
Steps over ditto on both sides of Fall	2	9	2	(1 + 4) × 0·5	90
Raised wall next to bridge ...	2	12	2	4	192
Flooring rectangle	1	41	30	2	2,460
Ditto 2 semi-circle (or circle) ...	1	41 × 41	0·7854	2	2,640
Ditto 7 feet in front of bridge ...	1	32	7	2	448
Ditto over blocks of steps ...	2	38	7	2	1,064
Back wall supporting steps ...	1	38	6	2	456
Ditto	1	38	4	3	452
Ditto	1	38	3	3	344
Steps and arches below, equal to	1	38	6	8	1,826
Abutment walls up to level of top step	2	14	4	7 × 0·5	392
Piers ditto ditto ...	3	14	2	7 × 0·5	294
Abutment up to ditto	2	21	4	4	672
Ditto to top	2	21	4	3	504
Piers up to top	3	21	2	8	1,008
Arches taken solid from spring ...	4	19	6	3·5	1,596
Lower wing walls...	2	11·75 × 3·14 × 0·5 × 2·5 ×		12·5	922
Ditto	2	11·50 × 3·14 × 0·5 × 2·0 ×		4·5	172
Parapets, upper curves	2	8	1·5	3	72
" over bridge	2	34	1·5	3	306
" lower curves	2	10·5 × 3·1,416	1·5	3 × 0·5	148
" Dwarf pillars	4	2	2	3	48
Steps below bridge, foundation, equal to	2	18·5	4	3·5	518
Ditto superstructure	2	18·5	6	(2 + 5) × 0·5	777
Total Masonry ...	...	......	......	......	33,938
Cut Stone-work.					
Sill of Fall...	1	30	2·5	1	75
Sides of ditto	2	3	1·5	3	27
Coping of parapets	......	116	2·0	0·5	116
String course below ditto ...	......	116	1·0	0·5	55
Ditto round peirs	8	22	1·0	0·5	88
Faces of arches	8	7	1·0	1·5	84
Total Cut-stone ...	...	......	......	.. ....	448

	No.	L.	B.	D.	Total.
Dry Stone-work.					
Above Fall...	1	35	10	2·5	875
Below bridge	1	25	18·5	2·5	1,156
At sides below steps	2	15	5	5	750
Total Dry Stone-work ...	...	......	......	......	2,781
Concrete.					
See items in flooring 1	...	......	......	......	2,460
" " 2	...	......	......	......	2,640
" " 3	...	......	......	......	448
Total Concrete ...	...	......	......	......	5,548
Excavation.					
Over all, including berm and omitting 30 feet of channel ...	1	72	50	4	14,400
Bason rectangle	1	50	30	17	25,500
Semi-circular	2	$50^2 \times 0{\cdot}7854$	0·5	17	33,379
Total Excavation ...	...	......	......	......	73,279
Metalling (whole length of work)	1	110	16	0·5	880
Planks for closing bridges ...	12×4	12	0·5	0·125	36

ABSTRACT.

		Rs.
73,279	Cubic feet excavation, at Rs. 6 per 1,000 cubic feet	440
33,938	Ditto Masonry, at Rs. 15 per 100 cubic feet	5,091
5,548	Ditto Concrete, at Rs. 12 per 100 cubic feet	666
25	Blocks, sinking, at Rs. 40 each	1,000
25	Blocks, curbs, at Rs. 20 each...	500
448	Cubic feet cut stone-work, at Rs. 30 per 100 cubic feet ...	134
2,781	Ditto dry stone-work work, with piling, at Rs. 8 per 100	222
36	Ditto planks, at Rs. 3 per cubic foot	108
880	Ditto metalling, at Rs. 6 per 100 cubic feet	53
	Unwatering	900
	Contingencies at 5 per cent.	456
	Total for one Fall 30 feet water-way Rs.	9,570

If the soil should be found favourable, so that block-sinking and any charge for unwatering should prove unnecessary, the cost may be reduced by the following items:—

	Rs.
Half of the masonry in blocks, or say 4,500 cubic feet	675
Curbs of blocks	500
Sinking of blocks	1,000
Unwatering	900
Contingencies at 5 per cent.	154
Total Rs.	3,229
Leaving the cost of the 30 feet Fall ... Rs.	6,341

The foregoing two Estimates, with the one given in the Estimate for Distributing Channels, are sufficient to show what the cost of Falls will be on the kind of design adopted. The following Table exhibits the cost as it will be taken in the Estimate :—

Water-way over sill.	Cost with undersunk foundations.	Cost with ordinary foundations.	Cost used in framing the General Estimate.
	Rs.	Rs.	Rs.
100	40,000	30,000	35,000
80	30,000	24,000	27,000
60	22,500	17,000	20,000
50	18,000	13,000	15,500
40	13,500	10,000	11,500
30	9,000	6,000	7,500
25	7,500	4,500	5,500
20	6,000	3,500	4,000
15	4,500	2,500	3,000
10	3,000	1,500	2,000
7	750	1,500	1,000

A. Single Lock with waste weir and navigable channel separate from the main canal.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	3	(9 x 6)– (6 x 3)		13	1,404
Ditto	1	(9 x 6.5)–(6 x 3·5)		13	487
Ditto	2	(8 x 7)–(5 x 4)		13	936
Ditto	15	(9 x 7)–(6 x 4)		13	7,605
Ditto	1	(9·5 x 7)–(6·5 x 4)		13	526
Ditto	3	(10 x 7)–(7 x 4)		13	1,638
Ditto	6	(11 x 6)–(8 x 4)		13	3,510
Ditto	2	(12·5 x 7)–(9·5 x 4)		13	1,287
Ditto	7	(13 x 7)–(10 x 4)		13	4,641
Ditto	6	(13·5 x 7)–(10·5 x 4)		13	4,095
Ditto	1	(11 x 8)–(8 x 5)		13	624
Ditto	6	(13 x 8)–10 x 5		13	4,212
Flooring on lower level—					
1 over all from front blocks of lock to middle of bridge ...	1	132	32	2	8,448
2 ditto as far as rear of bridge..	1	8½	30	2	510
2nd ditto in lower portion of waste channel to rear of bridge	1	50	15	2	1,500
Across front blocks of tail ...	1	49	12·5	2	1,225
Next	1	67	7·5	2	1,005
Over tail line of blocks ...	1	86	7	2	1,204
Steps for fall in waste channel ...	1	10	4	3	120
Ditto ditto ditto ...	1	10	4	6	240
Ditto ditto ditto ...	1	10	2	2	40
Flooring of ditto	1	100	10	2	2,000
Wall of recess	1	13	3	6	234
Ditto ditto	2	6	3	6	216
Front curtain wall of ditto ...	1	10	5	2	100
Ditto ditto ditto ...	1	10	4	2	80
Ditto ditto ditto ...	1	10	3	2	60
Side wall at Mills	1	55	5	16	4,400
Ditto to curve of the upper wing...	1	67	4	16	4,288
Small arch over channel	1	10	6	4·5	270
Centre wall, upper end	1	20	9	2	360
Ditto ditto	1	19·5	9	2	351
Ditto ditto	1	19	9	4	684
Ditto ditto	1	8	8	8	512
Ditto ditto	1	6·5	9	8	468
Ditto ditto	...	9 x 9	·78	8	505
Curtain wall of lock chamber ...	1	19	5	2	190
Ditto ditto	1	19	4	2	152
Ditto ditto	1	19	3	2	114
Flooring above lock	1	19	18	2	684
Block under lock-gate right across	1	32	7	8	1,792
Straight wing above ditto ...	1	3	8	4	96
Carried over ...	...	.....	......	......	62,813

	No.	L.	B.	D.	Total.
Brought forward ...	...	......	......	......	62,813
Straight wing above lock gate right across	1	3	5	4	60
Ditto ditto	1	8	4	8	256
Ditto ditto	1	12	4	8	384
Curved wings,, (including semi-circle as 2)	4	3·14 x 13·5	4	16	1,085
Distributing channel head, curtain wall, upper	1	12	2	8	192
Ditto floor above bridge ...	1	8	$\frac{10+6}{2}$	1·5	96
Ditto abutments of bridge ...	2	19	3	14	1,596
Ditto tail curve	2	3·14 x 13·5	3	14	3,561
Tail curtain wall	1	8	2	6	96
Flooring	1	4	7	1·5	42
Centre flooring	1	19	6	1·5	171
Bridge taken solid from spring ...	1	19	6	4	456
Parapets	2	12	1·5	3	108
Centre wall of lock chamber from drop to recess for lower lock ...	1	105	9	16	15,120
Side ditto ditto ditto... ...	1	105	8	10	8,400
Ditto ditto ditto... ...	1	105	5	6	3,150
Buttresses	9	4	$\frac{1+2}{2}$	4	216
Side waste channel wall below Mills	1	53	5	16	4,240
Centre walls at recess of lock ...	1	12	8	16	1,536
Ditto side wall of locks	1	12	8	16	1,536
The same under bridge, 1st ...	1	19	9	21	3,591
Ditto ditto 2nd ...	2	19	5	21	1,990
Ditto ditto ditto ...	1	5	3	21	315
Steps in front of bridge, total length	1	15	10	5 x 0·5	375
Parapets to ditto	2	10	1·5	3	90
Bridges taken solid 2 feet above spring	1	16 + 10	19	4	1,976
Parapets	2	38	1·5	3	342
Tail steps	1	26	9	$\frac{2.5}{2}$	2,925
Parapets of ditto	2	25	1·5	3	225
Tail wings (mean height) ...	2	3·14 x 0.5	27·5 x 5	23	9,930
					1,26,873
Deduct hollows under upper lock..	1	16	3	4	192
Ditto in centre walls	7	10	3	5	1,050
Ditto ditto	7	10	2	3	420
					1,662
Total cubic feet of Masonry ...	...	......	......	......	1,25,211
Concrete.					
Lock chamber body	1	97	16	2	3,104
Waste channel	1	56	9	2	1,008
Carried over ...	...	......	......	......	4,112

	No.	L.	B.	D.	Total.
Brought forward ...	...	....	......	......	4,112
Lock chamber under bridge ...	1	19	15·5	2	589
Ditto below tail flooring	1	19	17	2	646
Waste chamber ditto	1	19	11·5	2	437
Sluice chamber	1	7	16	2	224
Ditto in waste channel	1	13	9	2	234
Total Concrete ...	...	......	......	......	6,242
Dry Stone-work.					
At head, say equal to	1	120	10	3	3,600
At Tail	1	100	10	3	3,000
Total Dry Stone-work ...	..	......	......	......	6,600
Wood-work.					
Lock gates, upper...	4	11·33	0·66	8	239
Ditto lower	4	11·33	0·66	16	478
Screen beams	4	19	0·75	0·75	43
Planks for stopping waste channel	...	10·5	8	0·12	10
Total Wood-work ...	...	...	...	...	770
Excavation.					
Lock channel upper width = 15, + 1·5 depth	1	3,300	27	8	712,800
Ditto Lower	1	3,300	39	16	2,059,200
This will cover the excavation for the lock chamber.					
Total Excavation ...	...	...	...	...	2,772,000
Cut Stone-work.					
Coping of parapets	...	150	2	0·5	150
String courses to ditto	...	100	1	0·5	50
Faces of arches	...	20	1·5	1·5	45
Seats for lock-gate pivots upper	2	8	2	1·5	96
Ditto ditto lower	2	16	2	1·5	36
Ditto for sills of both lock-gates...	4	12	2	1·5	144
Grooves in waste channel... ...	2	8	2	1·0	32
Ditto for mill sluices	12	8	1	0·5	48
Total Cut-stone ...	...	...	...	...	601

ABSTRACT.

		Rs.
2772,000	Cubic feet excavation, at Rs. 2-8 per 1000 cubic feet	6,930
	Contingencies, at 5 per cent.	346
	Total Navigable Channel ...	7,276
1,25,211	Cubic feet masonry, at Rs. 15 per 100 cubic feet	18,781
53	Curbs for blocks, at Rs. 25 each	1,325
53	Sinking blocks, at Rs. 50 each	2,650
6,242	Cubic feet concrete, at Rs. 12 per 100 cubic feet	749
6,600	Ditto dry stone-work with cribs and piles, at Rs. 10 per 100	660
770	Ditto wood-work, say at Rs. 5 per foot	3,850
601	Ditto Cut stone-work, at Rs. 30 per 100 feet extra charge...	181
5	Drum sluices, at Rs. 100 each	500
	Contingencies at 5 per cent.	1,435
	Total cost of lock ... Rs.	30,131
	Total lock and channel ...	37,407

If the soil prove favourable the following reductions may be made :—

	Rs.
Two-thirds of the masonary blocks, or say 20,000 cubic feet, at Rs. 15 per 100 feet	3,000
Curbs for blocks	1,325
Sinking blocks	2,650
Half the concrete, leaving the rest as equivalent to increased thickness of flooring	375
Contingencies, at Rs. 5 per cent.	367
Total reduction ...	7,717
Leaving the cost of the single lock	22,413
Add channel as before	7,276
Total for lock and channel ...	29,689

B. Double Locks with double Waste Channels on Main Canal, 4½ feet depth of water.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	6	(9 × 6) − (6 × 3)		13	2,808
Ditto	3	(9 × 6·5) − (6 × 3·5)		13	1,462
Ditto	45	(9 × 7) − (6 × 4)		13	22,815
Ditto	3	(9·5 × 7) − (6·5 × 4)		13	1,579
Ditto	7	(10 × 7) − (7 × 4)		13	3,822
Ditto	8	(11 × 7) − (8 × 4)		13	4,680
Ditto	2	(12·5 × 7) − (9·5 × 4)		13	1,287
Ditto	12	(13 × 7) − (10 × 4)		13	7,956
Ditto	9	(13·5 × 7) − (10·5 × 4)		13	6,142
Flooring on lower level—					
1st over all from front blocks of lock to middle of bridge, width 3 × 9 + 2 × 16...	1	132	59	2	15,576
2nd ditto as far as rear of bridge	1	8½	59	2	1,003
3rd lower portion of waste channels to rear of bridge ...	1	50	30	2	3,000
4th across front blocks of tail	1	92	12·5	2	2,300
" next blocks of tail ...	1	110	7·5	2	1,650
" last line of blocks at tail ...	1	130	7	2	1,820
Steps for fall in waste channel ...	2	10	4	3	240
Ditto ditto ditto ...	2	10	4	6	480
Ditto ditto ditto ...	2	10	2	2	80
Flooring of waste channel, upper level	2	100	10	2	4,000
Walls of recesses	2	13	3	6	468
Ditto	4	6	3	6	432
Front curtain wall of waste channel	2	13	5	2	260
Ditto ditto ditto ...	2	13	4	2	208
Ditto ditto ditto ...	2	13	3	2	156
Side wall at Mills	2	55	5	14	7,700
Ditto to head of small bridges ...	2	31	4	14	3,472
Small arches over channels ...	2	10	6	4·5	540
Foundation of centre walls, upper	3	20	9	2	1,080
Ditto ditto ditto ...	3	19·5	9	2	1,053
Ditto ditto ditto ...	3	19	9	4	2,052
Centre wall upper end, superstructure	2	8	8	6	768
Ditto ditto ditto ...	1	8	7	6	336
Ditto ditto ditto ...	3	6·5	9	6	1,053
Ditto ditto ditto ...	3	9 × 9	0·78	6	1,137
Curtain walls to 2 lock chambers	2	16	5	2	320
Ditto ditto ditto ...	2	16	4	2	256
Ditto ditto ditto ...	2	16	3	2	192
Flooring above lock	2	19	16·5	2	1,254
Blocks under lock gates right across both locks and 3 walls ...	2	59	7	8	6,608
Carried over ...	...	......	......	......	1,12,015

	No.	L.	B.	D.	Total.
Brought forward ...	...	......	.....	....	1,12,045
Curved wings, including as two semi-circles of distribution channel heads	6	3·14 × 13·8	2·5	12	7,630
Distribution channel heads, centre walls upper	2	12	2	8	384
Ditto floor above bridge	2	8	$\frac{10+6}{2}$	1·5	192
Ditto abutments of bridges ...	4	19	3	12	2,736
Ditto tail curves	4	3·14 × 13·5	2·5	12	5,087
Ditto tail curtain walls	2	8	2	6	192
Ditto centre flooring	2	19	6	4	912
Ditto tail ditto	2	4	7	1·5	84
Ditto bridges taken solid from spring	2	19	6	4	912
Ditto parapets	4	12	1·5	3	216
Centre walls of locks from drop to recess for tail locks	3	105	9	14	39,690
Wall of waste channel below mills	2	53	5	14	7,420
Centre walls at recess of locks ...	2	12	8	14	2,688
Ditto ditto ditto ...	1	12	7	14	1,176
Centre walls under bridge ...	3	19	9	19	9,747
Side ditto	2	19	5	19	3,610
Steps in front of bridges (total length)	1	33	10	5 × 0·5	825
Parapets to ditto	6	10	1·5	3	270
Bridges taken solid 2 feet above spring of large arches	...	52	19	4	3,952
Parapets	2	68	1·5	3	612
Tail steps	3	26	9	$\frac{23}{2}$	8,073
Parapets of ditto	6	25	1·5	3	675
Tail wings (mean height) ...	2	3·14 × 0·5	27·5 × 5	21	9,067
					2,18,195
Deduct hollows under blocks ...	2	16	3	4	384
Ditto in centre walls in two ...	14	10	3	5	2,100
and	14	10	2	3	840
Add in one	10	10	3	5	1,500
and	10	10	2	3	600
					5,424
Total Masonry ...	...	.. ...	......	......	2,12,771
Concrete Work.					
Lock chambers	2	97	16	2	6,208
Waste channel	2	56	9	2	2,016
Lock chamber under bridge ...	2	19	15·5	2	1,178
Ditto below tail flooring	2	19	16	2	1,216
Carried over ...	...	......	......	......	10,618

	No.	L.	B.	D.	Total.
Brought forward ...	...	......	......	......	10,618
Waste channel tails	2	19	11·5	2	874
Sluice chambers of lock	2	7	16	2	448
Ditto waste channel	2	13	9	2	468
Total concrete ...	...	......	......	......	12,408
Cut Stone-work.					
Coping of parapets	...	334	2	0·5	334
String course to ditto	...	184	1	0·5	92
Faces of arches main bridge ...	...	40	1·5	1·5	90
Seats for lock-gate pivots, upper...	4	6·5	2	1·5	78
Ditto lower gates	4	14·5	2	1·5	174
Ditto sills both gates ...	8	12	2	1·5	288
Grooves in waste channels ...	4	6·5	2	1·0	52
Ditto for mill sluices	12	6·5	1	0·5	39
Total ...	...	......	......	......	1,147
Dry Stone-work.					
At head, say equal to	1	150	10	3	4,500
At tail	1	130	10	3	3,900
Total Dry Stone-work ...	...	...	...	...	8,400
Wood-work.					
Lock gates, upper...	4	11·33	0·66	6	179
Ditto lower...	4	11·33	0·66	14	419
Screen beams	4	19	0·75	0·75	43
Planks	...	10·5	6	0·12	8
Total Wood-work... ...	...	...	..	...	649
Excavation.					
For lock say	1	150	90	18	243,000
Widening above lock	1	300	$\frac{60}{2}$	6	54,000
Ditto below ditto	1	500	$\frac{60}{2}$	14	210,000
Total Excavation	...	...	...	...	507,000

ABSTRACT.

		Rs.
5,07,000	Cubic feet of excavation at Rs. 6 per 1,000 cubic feet	3,042
2,12,771	Ditto masonry, at Rs. 15 per 100 cubic feet	31,915
95	Block, sinking, at Rs. 50 each	4,750
95	Ditto, Curbs, at Rs. 25 each	2,375
8,400	Ditto Dry stone-work, at Rs. 8 per 100 cubic feet... ...	672
12,408	Ditto Concrete, at Rs. 12 per 100 cubic feet	1,489
1,147	Cubic feet cut stone-work, at Rs. 30 per 100 cubic feet... ...	344
649	Ditto Wood-work, at Rs. 5 per foot...	3,245
10	Drum sluices, at 100 each	1,000
	Contingencies, at 5 per cent.	2,448
	Total ...Rs.	51,420

If the soil should be favourable for foundations, the following reductions may be made :—

	Rs.
Two-thirds of the masonry in blocks, or say 34,000 cubic feet, at Rs. 15 per 100 feet	5,100
Curb frames for blocks	2,375
Sinking blocks	4,750
Half the cost of the concrete	745
Contingencies at 5 per cent.	648
Total reduction... ...	13,618
Leaving the cost of the double lock with two waste channels ... ...Rs.	37,802

C. Double Locks with single Waste Channel on Main Canal, 3½ feet depth of water.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	6	(9 × 6) – (6 × 3)		13	2,808
Ditto	2	(9 × 6·5 – (6 × 3·5)		13	975
Ditto	4	(8 × 7) – (5 × 4)		13	1,872
Ditto	33	(9 × 7) – (6 × 4)		13	16,731
Ditto	2	(9·5 × 7 – (6·5 × 4)		13	1,053
Ditto	4	(10 × 7) – (7 × 4)		13	2,184
Ditto	12	(11 × 7) – (8 × 4)		13	7,020
Ditto	4	(12·5 × 7) – (9·5 × 4)		13	2,574
Ditto	2	(13 × 7) – (10 × 4)		13	1,326
Ditto	6	(13·5 × 7) – (10·5 × 4)		13	4,095
Ditto	2	(11 × 8) – (8 × 5)		13	1,248
Ditto	12	(13 × 8) – (10 × 5)		13	8,424
Flooring lower level—					
1st. Over all from front blocks of locks to middle of bridges	2	132	32	2	16,898
2nd. Ditto as far as rear of bridges ...	2	8½	30	2	1,020
3rd. Ditto in lower part of waste channel	1	50	10	2	1,000
Across front blocks of tail	1	74	12·5	2	1,850
Next	1	92	7·5	2	1,380
Over tail line of blocks	1	111	7	2	1,554
Steps for fall in waste channel ...	1	10	4	3	120
Ditto ditto ...	1	10	4	6	240
Ditto ditto ...	1	10	2	2	40
Flooring of waste channel above..	1	100	10	2	2,000
Walls of recess	2	10	3	6	360
Front centre wall of waste channel	1	10	5	2	100
Ditto ditto ...	1	10	4	2	80
Ditto ditto ...	1	10	3	2	60
Small arch over channel	1	10	6	4·5	270
Centre walls, foundation, upper end	2	20	9	2	720
Ditto ditto ...	2	19·5	9	2	702
Ditto ditto ...	2	19	9	4	1,368
Ditto superstructure ..	2	8	8	5	640
Ditto ditto ...	2	6·5	9	5	585
Ditto ditto ...	2	9 × 9	0·78	5	632
Curtain walls of lock chambers ...	2	19	5	2	380
Ditto ditto ...	2	19	4	2	304
Ditto ditto ...	2	19	3	2	228
Flooring above locks, mean width	2	19	18	2	1,368
Blocks under lock gate right across, omitting waste channel...	2	32	7	8	3,584
Straight wing walls above ditto...	2	3	8	2	96
Carried over ...	...	......	......	......	87,889

	No.	L.	B.	D.	Total.
Brought forward ...	...	......	......	......	87,889
Straight wing walls above ditto...	2	3	5	6	180
Ditto ditto ...	2	8	4	8	512
Ditto ditto ...	2	12	4	5	480
Curved wing walls, including, as 2, the semi-circular wings of channel	6	3·14 × 13·5	2·5	11	6,994
Distributing channel head, curtain wall, upper	2	12	2	6	288
Ditto floor above bridge	2	8	$\frac{10+6}{2}$	1·5	192
Ditto abutments of bridge ...	4	19	3	11	2,508
Ditto tail curves	4	3·14 × 13·5	2	10	3,391
Tail curtain wall...	4	8	2	4	256
—— Flooring	2	4	7	1·5	84
Centre ditto	2	19	6	1·5	342
Bridges taken solid	2	19	8	4	1,216
Parapets	2	12	1·5	3	216
Centre walls of lock chamber ...	2	105	9	13	24,570
Side ditto	2	105	8	7	11,760
Side walls of lock chambers ...	2	105	5	6	6,300
Buttresses	1·8	4	$\frac{1+2}{2}$	4	43
Centre walls at recess of lock ...	2	12	8	13	2,496
Side wall ditto	2	12	8	13	2,496
Centre walls under bridge ...	2	19	9	17	5,814
Side ditto	2	19	5	17	3,230
Portion of ditto	2	5	3	17	510
Steps in front of bridge	...	26	10	5 × 0·5	650
Parapets to ditto	4	10	1·5	3	180
Bridges taken solid	...	42	19	4	3,192
Parapets	2	58	1·5	3	522
Tail steps	2	26	9	$\frac{22}{2}$	5,148
Parapets of ditto	4	25	1·5	3	450
Tail wings	2	3·14 × 0·5	27·5 × 5	20	8,635
Deduct	...	...	...	...	1,80,544
Hollow under locks	2	16	3	4	384
Ditto in centre walls	14	10	3	4	1,680
Ditto ditto	14	10	2	3	840
					2,904
Total Masonry ...	...	...	...	...	1,77,640
Concrete.					
Lock chamber, to bridge... ...	2	97	16	2	6,208
Waste channel	1	56	9	2	1,008
Lock chamber under bridges ...	2	19	15·5	2	1,178
Carried over ...	...	......	.. ...	... ..	8,394

	No.	L.	B.	D.	Total.
Brought forward ...	...	......	......	......	8,394
Lock chamber below tail floor ...	2	19	17	2	1,292
Ditto tail of waste channel ...	1	19	9·5	2	361
Sluice chamber	2	7	16	2	448
Ditto in waste channel	1	13	10	2	260
Total Concrete ...	...	...	...	...	10,755
Dry Stone-work.					
At head say	1	140	10	3	4,200
At tail	1	120	10	3	3,600
Total Stone-work ...	...	...	...	...	7,800
Wood-work.					
Lock gates, upper...	4	11·33	0·66	5	149
Ditto lower...	4	11·33	0·66	13	389
Screen beams	8	19	0·75	0·75	85
Planks for waste channel... ...	...	10·5	6	0·12	7
Total ...	...	...	...	...	630
Excavation.					
Lock excavation	1	150	75	17	191,250
Widening channel, above ...	1	300	$\frac{50}{2}$	5	37,500
Ditto below	1	500	$\frac{60}{2}$	13	195,000
Total Excavation ...	...	...	...	...	423,750
Cut Stone-work.					
Coping of parapets	...	240	2	0·5	240
String course of ditto	...	140	1	0·5	70
Ditto of arches	...	33	1·5	1·5	74
Seats for lock gate pivots, upper	4	3·5	2	1·5	42
Ditto ditto, lower	4	11·5	2	1·5	138
Ditto sills	8	12	2	1·5	288
Grooves in waste channel ...	2	3·5	2	1·0	14
Ditto for mill sluices	12	3·5	1	0·5	21
Total Cut Stone-work ...	...	...	...	...	887

ABSTRACT.

		Rs.
423,750	Cubic feet of excavation, at Rs. 6 per 1,000 cubic feet	2,542
177,640	Ditto masonry, at Rs. 15 per 100 cubic feet	26,646
89	Blocks, sinking, at Rs. 50 each	4,450
89	Ditto, curbs, at Rs. 25 each	2,225
7,800	Cubic feet dry stone-work, at Rs. 8 per 100 cubic feet	624
887	Ditto cut-stone work, extra charge, at Rs. 30 per 100 cubic feet	266
10,755	Ditto concrete, at Rs. 12 per 100 cubic feet	1,291
630	Ditto wood-work, at Rs. 5 per cubic foot	3,150
10	Drum sluices, at Rs. 100 each	1,000
	Contingencies at 5 per cent.	2,109
	Total Rs. ...	44,303

If the soil be such as not to render block-sinking necessary, the following reductions may be made:—

	Rs.
Two-thirds of the masonry in blocks, or say 27,500 cubic feet	4,125
Curbs for blocks	1,780
Sinking ditto	3,560
Half the concrete	645
Contingencies	505
Total reduction	10,615
Leaving the cost of each double lock with single waste channel, Rs.	33,688

D. Mills.

	No.	L.	B.	D.	Total.
Masonry.					
Waste channel walls ...	2	60	2	5·6	1,560
Ditto floor	1	60	6	1·5	540
Ditto arches	1	60	6	2	720
Drain channel walls	2	25	2	6	600
Ditto floor	1	25	4	1·5	150
Ditto arches	1	25	4	2	200
Mill chamber walls, foundation ...	2	24·5	2·5	2·5	306
Ditto ditto ...	4	20·5	2·5	2·5	513
Ditto plinth ...	2	24	2	4·5	432
Ditto ditto ...	4	21	2	4·5	756
Ditto superstructure	4	23	1·5	7·5	1,035
Ditto ditto ...	4	21	1·5	7·5	945
Flooring below mill wheels ...	6	5	3·5	1·5	157
Ditto of mill chamber	2	21	20	1·0	840
Partition walls	8	3·5	1	3·5	98
Steps, back wall	1	7·5	2·5	6·0	112
Ditto and arch, equal to... ...	1	7	7·5	2·5	131
Flooring below steps ...	1	7	5·0	1·5	52
Total ...	...	...	...	...	9,147
Deduct doors	2	6·5	4	1·5	78
Total Masonry ...	...	...	..	...	9,069
Roofing, including wood-work, superficial feet	2	21	20	...	840
Doors	2	6·5	4	...	52
Sets of Mill Machinery	6				

ABSTRACT.

		Rs.
9,069	Cubic feet of masonry, at Rs. 15 per 100	1,360
840	Superficial feet roofing, at Rs. 40 per 100	336
52	Ditto doors, at R. 1 per foot	52
6	Sets of mill machinery, at Rs. 50 each	300
	Contingencies at 5 per cent.	102
	Total 2 Mills, with 6 stones in all ... Rs.	2,150

Estimate No. 11, locks and mills.

E. Small locks 60 × 10 *for the minor channels.*

	No.	L.	B.	D.	Total.
Masonry.					
Straight portion (7·5 + 60 + 19) of walls of lock chamber, deep part	2	82	5	15	12,300
Ditto shallow part	2	4·5	5	15	675
Deep portion waste channel wall...	1	40	5	15	3,000
Shallow portion	1	46·5	3	7	977
Upper wings	2	$\frac{3 \cdot 1416}{2}$	13 × 2	7	572
Lower ditto	2	$\frac{3 \cdot 1416}{2}$	21·5 × 5	13	4,390
Head of centre wall	1	3	5	7	105
Tail steps of ditto	1	20 × 0·5	12	5	600
Flooring lock chamber	1	86·5	10	3	2,595
Ditto of waste chamber	1	86·5	6	3	1,557
Ditto of tail wings	1	20	$\frac{60+21}{2}$	2	1,620
Curtain walls above lock and waste chamber	1	16	3	2	96
Ditto for drops in ditto	1	16	8	3	384
Ditto below tail	1	60	4	2	480
Walls of sluice recess below lock	2	18	4	3	432
Ditto ditto ditto ...	2	5	4	3	120
Ditto ditto in waste channel ...	1	9	3	3	81
Ditto ditto ditto ...	2	5	3	3	90
Main bridge, both channels, taken solid from spring	1	10 + 6	19	4	1,216
Mill bridge	1	6	6	4	144
Upper lock ditto	1	6	6	4	144
Parapets of main bridge... ...	2	21	1·5	3·5	121
Dwarf pillars at ends	4	2	2	3·5	56
Total ...	...	...	...	...	31,755
Deduct hollows for upper gates ...	2	7·5	1	4	60
Ditto lower ditto ...	2	7·5	1	12	180
Total deducted ...	...	...	...	...	240
Total Masonry ...	...	...	...	...	31,515
Dry Stone-work.					
At head	1	30	10	2	600
At tail	1	60	15	2·5	2,500
Total Dry Stone-work ..	...	.. ...	......	......	2,250

	No.	L.	B.	D.	Total.
Cut Stone-work.					
Seat for pivots, upper gates ...	2	4	2	1·5	24
Ditto lower ditto ...	2	12	2	1·5	72
Ditto Sill, upper and lower gates	4	7·25	2	1·5	87
Coping of parapets	...	50	2·0	0·5	50
String course of ditto	...	50	1·0	0·5	25
Faces of arches, 10 feet span ...	2	12	1·0	1·5	36
Ditto 6 ditto ...	6	7	1·0	1·5	63
Grooves for waste channel ...	2	4	1·0	0·5	4
Ditto mill sluices	6	4	1·0	0·5	12
Total Cut Stone-work ..	...	......	......	......	373
Excavation	1	90	30	15	40,500
Wood-work.					
Upper gates	2	7·25	0·33	4	19
Lower ditto	2	7·25	0·50	12	87
Screen beams	4	13	0·50	0·50	13
Planks for waste channel... ...	1	6·5	4	0·083	2
Total Wood-work ...	...	......	......	......	121

ABSTRACT.

			Rs.
31,515	Cubic feet of	masonry, at Rs. 15 per 100 cubic feet	4,727
40,500	Ditto	excavation, at Rs. 5 per 1,000 cubic feet	202
2,850	Ditto	dry stone-work, at Rs. 8 per 100 cubic feet ...	228
373	Ditto	cut stone-work, at Rs. 30 per 100 cubic feet ...	112
121	Ditto	wood-work, at Rs. 5 per cubic foot	605
5	Small drum	sluices, at Rs. 30 each...	150
	Contingencies at 5 per cent.	... ...	301
		Total ... Rs.	6,325

No. 12, Barrier Bridges.

A. For Wings with semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Curved quadrantal wings, foundation	9	10·75 × 3·14 × 0·5 × 3·5		6	3,190
Ditto superstructure	9	10·5 × 3·14 × 0·5 × 3		7·5	3,338
Curved projection inside of lock channel head, foundation ...	2	4·75 × 3·14 × 0·75 × 3·5		6	466
Ditto superstructure	2	4·5 × 3·14 × 0·75 × 3		7·5	477
Sides of lock channel head and abutment of bridge, foundation..	6	31	3·5	6	3,906
Ditto superstructure	6	31	3	7·5	4,185
Floor of lock channel head ...	2	31	17	1·5	1,581
Curtain wall of lock channel ...	4	17	2	4·5	612
Ditto of half-span of bridge ...	4	2·5	2	6·0	120
Floor of ditto	2	13	2·5	1·5	97
Half arches taken solid from spring	2	15	3	3	270
Parapets of ditto	4	3	1·5	2·5	45
Corner pillars	4	2	2	2·5	40
Total Masonry ...	...	...	...	...	18,327
Cut Stone-work.					
Coping pillars	4	2·5	2·5	0·5	12
Ditto parapets	4	3	1·75	0·5	11
Arch, faces	2	7	1·5	1·5	31
Total Cut-stone ...	...	...	...	...	54

ABSTRACT.

		Rs.
18,327	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	2,749
54	Ditto cut-stone, at Rs. 30 per 100 cubic feet extra	16
	Contingencies at 5 per cent.	138
	Total ... Rs.	2,903

B. Pier with two semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Pier foundation	1	17	3	6	306
Ditto superstructure, taken square	1	17	2	5	170
Curtain wall of one span ...	2	5	2	6	120
Flooring ditto	1	13	5	1·5	97
All above spring of arch, taken solid	1	15	8	3	360
Parapets	2	8	1·5	2·5	60
Total Masonry ...	...	......	......	......	1,113
Cut Stone-work.					
Parapets, coping	2	8	1·75	0·5	14
String course	2	8	0·5	0·5	4
Piers, caps	2	2	2	1	8
Arch, faces	2	7	1·5	1·5	31
Total Cut Stone-work ...	...	......	......	......	57

ABSTRACT.

		Rs.
1,113	Cubic feet of masonry. at Rs. 15 per 100 cubic feet	167
57	Ditto extra cut-stone, at Rs. 30 per 100 cubic feet	17
	Contingencies at 5 per cent.	9
	Total ... ... Rs.	193

GENERAL ABSTRACT.

	Rs.	Amount taken in General Estimate. Rs.
Lock heads with wing walls and one span of bridge, Abstract A	2,903	29,00
Add for 1 span, as per Abstract B	193	
Total 2 spans	3,096	3,100
Add for 1 span, as per Abstract B.	193	
Total 3 spans	3,289	33,00
Add for 1 span, as per Abstract B.	193	
Total 4 spans	3,482	3,500
Add for 1 span, as per Abstract B.	193	
Total 5 spans	3,675	3,700

No. 13, Bridges.

A. Designs Nos. I. and III.

a. Abutments with two semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	8	$(8 \times 7 - 5 \times 4)$		12	3,456
Ditto	12	$(12 \times 7 - 9 \times 4)$		12	6,912
Ditto	4	$(13 \times 7 - 10 \times 4)$		12	2,448
Flooring over all as far as back of abutments	2	26·5	33	2	3,498
Ditto over blocks supporting steps	8	12	7	2	1,344
Abutments up to level of tow-path	2	19	16	10	6,080
Ditto next portion above ...	2	19	10	4	1,520
Ditto back of spring of arch ...	2	19	$\frac{8+6}{2}$	4	1,064
Ditto back of spandrill	2	19	4	4	608
Wing walls, first	4	$\frac{3·1416}{6} \times 28·5$	3	18	3,222
Ditto second	4	$\frac{3·1416}{6} \times 28$	2	14	1,642
Ditto square ends	4	3	3	14	504
Over steps of abutment	4	2	3	10	240
Ditto	4	2	3	6	144
Ditto	4	8	3	2	192
Cut-waters of abutments... ...	4	$\frac{2}{3} \times 7$	6	15	1,680
Caps over ditto	4	$\frac{2}{3} \times 6$	$\frac{1}{2}$	2	64
Starlings	4	0·7854	$6 \times 6 \times 0·5$	9	509
Two semi-arches	1	37·5	19	3	2,137
Two semi-spandrills	1	$(36·6 \times 9 - 152)$		19	3,363
Parapets over semi-arches ...	4	16·5	1·5	3·5	346
Ditto starlings	4	$\frac{3·1416}{2}$	6	$1·5 \times 3·5$	198
Ditto wing walls ...	4	$\frac{3·1416}{3}$	27·75	$1·5 \times 3·5$	605
Ditto dwarf pillars ...	4	3	3	3·5	126
Steps adjoining towing path ...	4	10	$\frac{17+6}{2}$	10	4,600
And ...	4	16	$\frac{17+6+2}{3}$	10	5,333
					51,835
Deduct—Hollow under tow path	2	19	3·5	6	798
Step in back of abutment, included in spandrill and wing walls	2	19	4	2	304
					1,102
Total Masonry ...	......	......	......	......	50,723

	No.	L.	B.	D.	Total.
Earth-work.					
Approaches, average section ...	2	450 × ½	$\frac{20+70}{2}$	15	303,750
Raising side ramps	4	220 × ½	$\frac{20+70}{2}$	11	217,800
These will more than cover extra width of channel.				Total ...	521,550
Metalling.					
Over semi-arches and abutments...	2	16½ + 6	16	0·5	360
Between wing walls	2	22	$\frac{38+16}{2}$	0·5	594
Total Metalling ...	......	......	......	......	954
Cut Stone-work.					
Coping of parapets (total length)	......	232	2	0·5	232
String course below ditto ...	......	232	1·0	0·5	116
Do. round heads of abutments ...	2	56	1·0	0·5	56
Do. in wing walls to correspond...	4	30	1·0	0·5	60
Facing of semi-arches	2	37·5	2·0	3·0	450
Total ...	......	......	......	......	914

ABSTRACT.

		Rs.
5,21,550	Cubic feet of earth-work, at Rs. 3 per 1,000 cubic feet... ...	1,565
48,586	Ditto masonry, at Rs. 15 per 100 cubic feet	7,287
2,137	Ditto ditto in arch, at Rs. 25 per 100 cubic feet ...	534
24	Blocks, sinking, at Rs. 50 each	1,200
24	Curbs for blocks, at Rs. 25 each	600
914	Cubic feet cut stone-work (extra charge) at Rs. 30 per 100 ...	274
954	Ditto metalling, at Rs. 6 per 100 cubic feet	57
	Contingencies at 5 per cent....	575
	Total cost of one span of 33 feet ... ... Rs.	12,092

If under-sunk foundations be not necessary, the following reductions may be made:—

Half the masonry in blocks, or say 6,400 cubic feet, at Rs. 15 per 100...Rs.	960
Sinking blocks	1,200
Curb frames	600
Contingencies	138
Total reduction ...	2,898
Leaving the cost of the one span of 33 feet ...Rs.	9,194

No. 13, Bridges.

A. Designs Nos. I. and III.

b. Pier with two semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation Blocks	2	(8 × 7 − 5 × 4)		12	864
Ditto	4	(12 × 7 − 9 × 4)		12	2,304
Ditto	2	(13 × 7 − 10 × 4)		12	1,224
Flooring over all	1	39	33	2	2,574
Pier	1	19	6	15	1,710
Ditto between skew backs ...	1	19	$\frac{6+2}{2}$	2·5	190
Cut-waters	2	$\frac{3}{4} \times 7$	6	15	840
Caps over cut-waters ...	2	$\frac{3}{4}$	$\frac{6+4}{2}$	2	32
Starlings	2	$\frac{0·7854}{2}$	6 × 6	9	254
2 semi-arches as in *a.*	...	......	...	...	2,137
2 semi-spandrills as ditto... ...	...	......	...	...	3,363
Span between spandrills	1	19	6·5	2	247
Parapets over arch	2	33	1·5	3·5	346
Ditto over starlings	2	$\frac{3·1416}{2}$	6 × 1·5	3·5	99
Total	...	......	...	...	16,184
Cut Stone-work.					
Coping of parapets (see length above)	..	85	2·0	0·5	85
String course under ditto ...	...	85	1·0	0·5	42·5
Ditto round pier	2	33	1·0	0·5	33
Facing of semi-arches	2	37·5	2·0	3·0	450
Total	...	......	...	...	610
Metalling	1	39	16	0·5	312

ABSTRACT.

		Rs.
14,047	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	2,107
2,137	Ditto ditto in arch, at Rs. 25 per 100 cubic feet ...	534
8	Blocks, curb frames, at Rs. 25 each	200
8	Ditto, sinking, at Rs. 50 each	400
610	Cubic feet of cut stone-work, at Rs. 30 per 100 cubic feet ...	183
312	Ditto metalling, at Rs. 6 per 100 cubic feet	19
	Contingencies at 5 per cent.	172
	Total ... Rs.	3,615

If block-sinking should not be necessary, the following reductions may be made:—

Half the masonry in blocks, or say 2,000 cubic feet, at Rs. 15 per 100	300
Curbs for blocks	200
Sinking ditto	400
Contingencies at 5 per cent.	45
Total ...	945
Leaving the cost of pier and two semi-spans Rs.	2,670

GENERAL ABSTRACT.

No. of Spans.	With cost of block-sinking.	Without cost of block-sinking.	Average.	Amount used in General Estimate.
One span (as per Abstract *a*) ...	12,092	9,194	10,643	
Add as per Abstract *b* ...	3,615	2,670		
Two spans as in design No. III. ...	15,707	11,864	13,785	15,500
Add again	3,615	2,670		
Three spans as in design No. I. ...	19,322	14,534	16,928	19,000
Add again	3,615	2,670		
Four spans as in Tootla drainage...	22,937	17,204	20,066	
Add again	3,615	2,670		
Five spans as in deep cutting west Sasseram	26,552	19,874	23,213	26,500

For the bridges of 3, 4, and 5 spans I have made no deduction, in anticipation of being able to save block-sinking in the foundations, as the cutting is generally deep, and springs are therefore likely to be met with. The bridges of 5 spans in the deep cutting will have higher piers, as shown in the elevation in Plate XX., but as the abutment foundations will, under that arrangement, be laid dry, causing a saving nearly equal to the cost of raising the piers, no alteration is made in the estimate on that account.

No. 13, Bridges.

B. Designs II. and VI.

a. Abutments with two semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	8	$(8\times7-5\times4)$		12	3,456
Ditto	16	$(9\times7-6\times4)$		12	7,488
Ditto (No. $4\times1\frac{1}{2}=$)	6	$(13\times7-10\times4)$		12	3,672
Flooring to back of abutment ...	2	$18{\cdot}5+11$	33	2	3,894
Ditto over blocks for steps ...	12	9	7	2	1,512
Abutments up to top of tow-paths	2	19	17	8	5,168
Ditto next portion	2	19	11	3	1,254
Ditto above that	2	19	9	1·5	513
Ditto behind skew back ...	2	19	$\frac{9+7}{2}$	2·5	760
Ditto behind spandrill ...	2	19	4	6	912
Wing walls, first	4	$\frac{3{\cdot}1416}{6}\times26$	3	18	2,940
Ditto second	4	$\frac{3{\cdot}1416}{6}\times25{\cdot}5$	2	14	1,495
Ditto third	4	3	3	14	504
Ditto over steps of abutment	4	2	3	12	288
Ditto ditto ditto	4	3	3	8	288
Ditto ditto ditto	4	11	3	2	264
Cut-waters of abutments... ...	4	$\frac{2}{3}\times7$	6	15	1,680
Caps over ditto	4	$\frac{2}{3}\times6$	$\frac{4}{2}$	2	64
Starlings	4	0·7854	$6\times6\times0{\cdot}5$	9	509
Two semi-arches	...	42·7	19	3	2,433
Two semi-spandrills	...	$(9{\cdot}7\times40{\cdot}6-213)$		19	3,435
Parapets over semi-arches ...	4	18·5	1·5	3·5	388
Ditto starlings	4	$\frac{3{\cdot}1416}{2}$	$6\times1{\cdot}5$	3·5	197
Ditto wing walls... ...	4	$\frac{3{\cdot}1416}{3}$	$25{\cdot}25\times1{\cdot}5$	3·5	556
Ditto dwarf pillars ...	4	3	3	3·5	126
Steps adjoining towing path, say	4	10	$\frac{14+2}{2}$	8	2,560
Ditto ditto ditto ...	4	18	$\frac{14+2+2}{3}$	8	3,456
Total ...	...	...	...	...	49,612
Deduct, Hollows under tow-paths	2	19	4	4	608
Steps between wing walls included in spandrill and wing walls ...	2	19	7	2	632
Total deductions ...	...	...	...	...	1,240
Total Masonry ...	...	...	...	...	48,372

	No.	L.	B.	D.	Total.
Earth-works.					
In approaches	2	$\frac{450}{2}$	$\frac{20+70}{2}$	15	303,750
In raising side ramps	4	$\frac{220}{2}$	$\frac{20+70}{2}$	11	217,800
These will more than cover the extra width of channel.					
Total Earth-work ...	...	...	...	...	5,21,550
Metalling.					
Over semi-arches and abutments...	2	18·5+6	16	0·5	392
Between wing walls	2	24	$\frac{44+16}{2}$	0·5	720
Total ...	...	...	...	...	1,112
Cut Stone-work.					
Coping of parapets (total length)...	...	230	2	0·5	230
String course below ditto... ...	...	230	1	0·5	115
Ditto round heads of abutments...	2	56	1	0·5	56
Ditto in wing walls to correspond	4	30	1	0·5	60
Faces of semi-arches	2	42·7	2	3	512
Total Cut-stone ...	...	...	...	...	973

ABSTRACT.

		Rs.
521,550	Cubic feet of earth-work, at Rs. 3 per 1,000 cubic feet	1,565
45,939	Ditto masonry, at Rs. 15 per 100 cubic feet	6,890
2,433	Ditto ditto in arch, at Rs. 25 per 100 cubic feet	608
30	Blocks, curb frames, at Rs. 25 each	750
33	Ditto sinking, at Rs. 50 each...	1,500
973	Cubic feet cut stone-work, at Rs. 30 per 100 cubic feet	292
1,112	Ditto metalling, at Rs. 6 per 100 cubic feet	67
	Contingencies at 5 per cent.	588
	Total cost of one span of 37 feet...	Rs. 12,350

If under-sunk foundations are not required, the following reductions may be made:—

	Rs.
Half the masonry in blocks, or say 7,000 cubic feet, at Rs. 15 per 100 cubic ft.	1,050
Sinking blocks	1,500
Curbs for ditto	750
Contingencies	165
Total ...	Rs. 3,465
Leaving the cost of 1 span of 37 feet ...	Rs. 8,885

No. 13, Bridges.

B. Designs Nos. II. and VI.

b. Pier with two semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	2	(8 × 7 − 5 × 4)		12	864
Ditto	6	(13 × 7 − 10 × 4)		12	3,672
Flooring over all	1	43	33	2	2,838
Pier	1	19	6	12·5	1,425
Ditto between skew backs ...	1	19	$\frac{6+2}{2}$	2·5	190
Cut-waters	2	$\frac{2}{3} \times 7$	6	12·5	700
Caps over cut-waters	2	$\frac{2}{3} \times 6$	$\frac{4}{2}$	2	32
Starlings	2	$\frac{\cdot 7854}{2}$	6 × 6	$9\frac{2}{3}$	273
2 semi-arches as in *a*	...	...	...	...	2,433
2 semi-spandrills ditto	...	...	...	...	3,435
Space between spandrills... ..	1	19	6·33	2	241
Parapets over arch	2	37	1·5	3·5	388
Ditto over starlings	2	$\frac{3 \cdot 1416}{2}$	6 × 1·5	3·5	99
Total Masonry ..	...	...	...	...	16,590
Cut Stone-work.					
Coping of parapets (see length above)	...	93	2·0	0·5	93
String course under ditto ...	...	93	1·0	0·5	46
Round pier	..	56	1·0	0·5	28
Facing of semi-arches	2	42·7	2	3	512
Total Cut Stone-work ...	...	...	...	...	679
Metalling	1	43	16	·5	354

ABSTRACT.

		Rs.
14,157	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	2,123
2,433	Ditto arch, at Rs. 25 per 100 cubic feet	608
8	Blocks, curb frames, at Rs. 25 each	200
8	Sinking blocks, at Rs. 50 each	400
679	Cubic feet of cut stone-work, at Rs. 30 per 100 cubic feet ...	204
354	Ditto metalling, at Rs. 6 per 100 cubic feet	21
	Contingencies, at 5 per cent.	178
	Total ...Rs.	3,734

If block-sinking should not be necessary, the following reduction may be made:—

	Rs.
Half the masonry in blocks, or say 2,100 cubic feet, at Rs. 15 p. 100 cubic ft.	315
Curbs for blocks	200
Sinking ditto	400
Contingencies at 5 per cent.	47
Total ... Rs.	962
Leaving the cost of pier and two semi-spans ... "	2,772

GENERAL ABSTRACT.

No. of Spans.	With cost of block-sinking.	Without cost of block-sinking.	Average.	Amount used in General Estimate.
One span—(Design No. VI.) as per Abstract *a*	12,350	8,885	10,467	10,000
Add as per Abstract *b*	3,734	2,772		
Two spans as in Design No. II. ...	16,084	11,657	13,870	16,000
Add again	7,468	5,544		
Four spans for the deep cutting ...	23,552	17,201	20,376	23,500

For the bridges of 3 and 4 spans I have made no deduction in anticipation of being able to save block-sinking in the foundations, as the cutting is generally deep and springs are therefore likely to be met with. The bridges of four spans in the deep cutting will have higher piers, as shown in the elevation in Plate XX., but as their abutment foundations will, under that arrangement, be laid dry, causing a saving nearly equal to the cost of raising the piers, no alteration is made in the estimate on that account.

No. 13, Bridges.

C. Designs Nos. IV. and VII.

a. Abutments with two semi-arches.

	No.	L.	D.	B.	Total.
Masonry.					
Foundation blocks	8	(11 × 7 − 8 × 4)		12	4,320
Ditto	7	(13 × 7 − 10 × 4)		12	2,448
Ditto	4	(15 × 7 − 12 × 4)		12	2,736
Flooring over all as far as back of abutments	2	24½	30	2	2,940
Ditto over blocks supporting steps	8	11	7	2	1,232
Abutments up to level of tow path	2	19	15	7	3,990
Ditto next portion above... ...	2	19	9	4	1,368
Ditto ditto	2	19	7	2⅓	621
Ditto at back of spring of arch...	2	19	$\frac{7+6}{2}$	1⅔	494
Ditto at back of spandrill ..	2	19	3¾	4	570
Wing walls, first	4	$\frac{3\cdot1416}{6} \times 28$	3	18	3,169
Ditto second	4	$\frac{3\cdot1416}{6} \times 27\frac{1}{2}$	2	14	1,613
Ditto square ends...	4	3	3	14	504
Ditto over steps of abutments ...	4	2	3	10	240
Ditto ditto	4	2	3	6	144
Ditto ditto	4	8	3	2	192
Cut-waters of abutments ...	4	⅔ × 6	5	13½	1,080
Caps over ditto	4	⅔ × 6	$\frac{2\frac{1}{2}}{2}$	2	40
Starlings	4	$\frac{0\cdot7854}{2}$	5 × 5	7⅔	300
2 semi-arches	1	31·7	19	2·5	1,506
2 semi-spandrills	1	(31 × 7⅔ − 113·2)		19	2,365
Parapets over semi-arches ...	4	15·5	1·5	3·5	325
Ditto starlings	4	$\frac{3\cdot1416}{2} \times 5$	1·5	3·5	165
Ditto wing walls	4	$\frac{3\cdot1416}{3}$	27·25 × 1·5	3·5	599
Ditto dwarf pillars	4	3	3	3·5	126
Steps adjoining towing path ...	4	10	$\frac{11+2}{2}$	7	1,820
And ...	4	12	$\frac{11+2+2}{3}$	7	1,680
					36,587
Deduct—					
Hollow under tow path ...	2	19	3	3	
Steps in back of abutments, included in spandrills and wing walls	2	19	8	2	950
Total Masonry ...	...	...	...	...	35,637

	No.	L.	B.	D.	Total.
Earth-work.					
Approaches, average section ...	2	$\frac{450}{2}$	$\frac{20+64}{2}$	14·5	274,050
Raising side ramps	4	$\frac{200}{2}$	$\frac{20+64}{2}$	10	168,000
These will more than cover the excavation for extra width of channel.					
Total Earth-work ...	...	...	...	...	442,050
Metalling.					
Over semi-arches and abutments	2	14+5	16	·5	304
Between wing walls	2	$\frac{46+16}{2}$	24	·5	744
Total Metalling... ...	...	...	...	...	1,048
Cut Stone-work.					
Coping of parapets (total length)	...	219	2·0	0·5	219
String course below ditto ...	...	219	1·0	0·5	110
Ditto round heads of abutments...	2	34	1·0	0·5	37
Facing of semi-arches	2	31·7	2·0	2·5	317
Total Cut Stone-work ...	...	...	...	...	680

ABSTRACT.

		Rs.
4,42,050	Cubic feet of earth-work, at Rs. 3 per 1,000 cubic feet	1,326
34,131	Ditto masonry, at Rs. 15 per 100 cubic feet	5,120
1,506	Ditto arch, at Rs. 25 per 100 cubic feet	376
19	Blocks, sinking, at Rs. 50 each	950
19	Ditto, curbs, at Rs. 25 each	475
680	Cubic feet of cut stone-work (extra charge), at Rs. 30 per 100...	240
1,048	Ditto metalling, at Rs. 6 per 100 cubic feet	63
	Contingencies at 5 per cent.	227
	Total cost of one span of 28 feet ...	Rs. 8,779

If under-sunk foundations be not necessary, the following reductions may be made:—

	Rs.
Half the masonry in blocks, or say 4,500 cubic feet	675
Sinking blocks	950
Curbs for blocks	475
Contingencies	105
Total reduction ...	2,205
Leaving the cost of the one span of 28 feet ...	Rs. 6,574

No. 13, Bridges.

C. Designs Nos. IV. and VII.

b. Pier with two semi-arches.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	3	$(13 \times 7)-(10 \times 4)$		12	1,836
Ditto	1	$(15 \times 7)-(12 \times 4)$		12	684
Flooring over all	1	33	30	2	1,980
Pier body	1	19	5	13·33	1,254
Cut-waters	2	$\frac{3}{4} \times 6$	5	13·33	533
Caps to ditto	2	$\frac{3}{4} \times 5$	4	2	53
Portion between skew backs ...	1	19	$\frac{2+5}{2}$	2·33	221
Starlings	2	$\frac{\cdot 7{,}854}{2}$	5×5	7·66	150
2 semi-arches (as in part *a*) ...	...	...	...	...	1,508
2 semi-spandrills ditto	...	...	...	...	2,365
Space between spandrills ...	1	19	2	6·33	241
Parapets over arch	2	28	1·5	3·5	147
Ditto starlings	2	$\frac{3{\cdot}1416}{2}$	$5 \times 1{\cdot}5$	3·5	82
Total Masonry ...	...	...	...	...	12,154
Cut Stone-work.					
Coping of parapets	...	72	2·0	0·5	72
String course of ditto	...	72	1·0	0·5	36
Ditto of head of pier	...	53	1·0	0·5	27
Facing of arch	2	31·7	2·0	2·5	317
Total Cut stone-work ...	...	...	...	...	452
Metalling.					
Roadway	1	33	16	0·5	264

ABSTRACT.

		Rs.
10,646	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	1,597
1,508	Ditto arching, at Rs. 25 per 100 cubic feet	377
4	Blocks, curb frames, large, at Rs. 30 each...	120
4	Sinking ditto, at Rs. 60 each	240
264	Cubic feet of metalling, at Rs. 6 per 100 cubic feet	16
	Contingencies at 5 per cent.	117
	Total ... Rs.	2,467

If under-sunk foundations be not necessary, the following reductions may be made:—

		Rs.
Half the masonry in blocks, or say 1,250 cubic feet, at Rs. 15...	...	187
Sinking blocks	...	240
Curb frames for ditto	...	120
Contingencies	...	27
Total	... Rs.	574
Leaving the cost of one span of 28 feet	... Rs.	1,893

GENERAL ABSTRACT.

	With under-sunk foundations.	Without under-sunk foundations.
Bridge of one span as per Abstract *a*—	8,779	6,574
Add per pier and semi-arches as per Abstract *b*. ...	2,467	1,893
Cost of bridge with 2 spans of 28 feet...	11,246	8,467

The cost of the bridge of one arch will be taken in the general estimate at Rs. 7,000, and the two arched bridge at Rs. 10,000.

No. 13, Bridges.

D. Design No. V.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation blocks	16	$(12\times7-9\times4)$		12	9,216
Ditto	4	$(14\times7-11\times4)$		12	2,592
Flooring over all	1	32	26	2	1,664
Ditto over blocks under steps...	8	12	7	2	1,344
Abutment up to top of tow-path..	2	19	16	5	3,040
Ditto above dittto ...	2	19	10	3·5	1,830
Ditto behind skew backs ...	2	19	$\frac{6+8}{2}$	2	753
Ditto ditto spandrill ...	2	19	6	1·66	380
Ditto ditto	2	19	4	5	760
Wing walls	4	$\frac{3·1416}{6}\times30·5$	3	19	3,641
Ditto	4	$\frac{3·1416}{6}\times30$	2	16	2,044
Ditto over steps of abutments...	4	2	3	11	264
Ditto ditto	4	2	3	7	168
Ditto ditto	4	12	3	2	288
Ditto ditto ends	4	3	3	16	576
Starlings of abutments	4	$\frac{·7854}{2}$	7×7	22	1,693
Arch	1	49·5	19	3·5	3,314
Spandrills	1	$48·2\times11·33-264$		19	5,360
Parapets over arch	2	44	1·5	3·5	462
Ditto starlings	4	$\frac{3·1416}{2}\times7$	1·5	3·5	230
Ditto wing walls	4	$\frac{3·1416}{3}\times29·75$	1·5	3·5	654
Ditto corners	4	3	3	3·5	126
Steps	4	10	$\frac{10+2}{2}$	4	960
Ditto	4	15	$\frac{10+2+2}{3}$	4	1,680
	...	...	...	...	42,539
Deduct—Hollow of towing path...	2	19	4	2	304
Step over abutments ...	2	19	8	2	608
	...	...	...	...	912
Total Masonry ...	...	...	...	...	41,627
Metalling.					
Over arch and abutments... ...	1	58	16	0·5	464
Between wing walls	2	$\frac{46+16}{2}$	28	0·5	864
Total Metalling ...	...	...	...	...	1,328

	No.	L.	B.	D.	Total.
Earth-work.					
In approaches	4	$\frac{240}{2}$	$\frac{70+20}{2}$	12	259,200
Ditto side	2	$\frac{450}{2}$	$\frac{70+20}{2}$	16	324,000
Total Earth-work ...	...	...	...	...	583,200
Cut Stone-work.					
Coping of parapets	...	268	2·0	0·5	268
String course of ditto	...	268	1·0	0·5	134
Heads of abutments ...	2	41	1·0	0·5	41
Facing of arch	2	49·5	2·0	3·5	693
Total ...	...	...	...	...	1,136

ABSTRACT.

		Rs.
583,200	Cubic feet of earth-work, at Rs. 2-8 per 1,000	1,458
38,313	Ditto masonry, at Rs. 15 per 100	5,747
3,314	Ditto arch, at Rs. 25 per 100	828
20	Blocks, curb frames, at Rs. 25 each	500
20	Ditto, sinking, at Rs. 50 each	1,000
1,328	Cubic feet of metalling, at Rs. 6 per 100	80
1,136	Ditto cut stone-work, at Rs. 30 per 100	341
	Contingencies at 5 per cent.	498
	Total for one span of 44 feet ... Rs.	10,452

If block-sinking be not necessary, the following reductions may be made:

	Rs.
Two-thirds of masonry in blocks, or 8,000 cubic feet, at Rs. 15 per 100 ...	1,200
Block sinking	1,000
Curb blocks	500
Contingencies at 5 per cent.	135
Total ... Rs.	2,835
Leaving the cost of one span of 44 feet... Rs.	7,617

The sum of Rs. 9,000 will be used in the General Estimate.

No. 13, Bridges.

E. Design No. VIII.

	No.	L.	B.	D.	Total.
Masonry.					
Abutments from bottom of foundation to top of tow-path ...	2	19	9	9·5	3,249
Curtain walls.	2	16	2	6	384
Curved walls of tow-paths ...	4	$\frac{3·1416}{2} \times 7$	2	6	528
Flooring	1	20	16	1·5	480
Abutments above tow-path ...	2	19	6	2·5	570
Ditto behind skew backs ...	2	19	$\frac{4+2·75}{2}$	3	343
Ditto behind spandrill ...	2	19	·75	3·5	100
Starlings	4	$\frac{0·7854}{2}$	5×5	19	746
Wing walls	4	$\frac{3·1416}{6} \times 16·75$	2·5	12·5	1,076
Ditto	4	$\frac{3·1416}{6} \times 16·5$	2	10·5	722
Ditto portion over steps of abutment	4	2	2·5	6·5	130
Ditto ditto ditto ...	4	2	2·5	3·5	70
End pillars	4	2·5	2·5	10·5	262
Arch	1	25	19	2	950
Spandrills	1	24·4 × 4·1—67·5		19	608
Parapets over arch	2	22	1·5	3·5	231
Ditto over starlings	4	$\frac{3·1416}{2} \times 5$	1·5	3·5	164
Ditto wing walls	4	$\frac{3·1416}{3} \times 16·25$	1·5	3·5	353
Dwarf pillars at ends	4	2·5	2·5	3·5	87
Deduct ...	...	...	...	...	11,053
Hollow under tow-paths	2	19	1·5	2	114
Total Masonry ...	...	...	...	...	10,939
Cut Stone-work.					
Coping of parapets	...	153	2·0	0·5	153
String course of ditto	...	153	1·0	0·5	76
Heads of abutments ...	2	34	1·0	0·5	34
Facing of arch	2	25	2·0	2·0	200
Total Cut Stone-work ...	...	...	...	...	463
Metalling.					
Over arch	1	22	16	0·5	176
Between wing walls	1	20	$\frac{32+16}{2}$	0·5	240
Total Metalling... ...	...	...	...	..	416

	No.	L.	B.	D.	Total.
Earth-work.					
In approaches	2	$\frac{285}{2}$	$\frac{20+48}{2}$	9·5	92,055
And side ramps	4	$\frac{130}{2}$	$\frac{20+48}{2}$	6·5	57,460
Total Earth-work ...	...	...	...	...	1,49,515

ABSTRACT.

			Rs.
1,49,515	Cubic feet of	earth-work, at Rs. 2-8 per 1,000	374
9,989	Ditto	masonry, at Rs. 15 per 100	1,498
950	Ditto	arch, at Rs. 20 per 100	190
416	Ditto	metalling, at Rs. 6 per 100	25
463	Ditto	cut stone-work, at Rs. 30 per 100	139
	Contingencies at 5 per cent.		111
		Total ... Rs.	2,337

Amount used in general estimate for bridge of 1 span of 22 feet ... " 2,300

No. 13, Bridges.

F. Design No. IX.

	No.	L.	B.	D.	Total.
Masonry.					
Abutment from bottom of foundation to top of tow-path ...	2	19	7	9	2,394
Curtain walls	2	12	2	6	288
Curved wings for tow-paths ...	4	$\frac{3{\cdot}1416}{2} \times 4$	2	9	452
Flooring	1	12	19·5	2	468
Abutments above tow-path ...	2	19	5	3·33	633
Ditto behind skew back ...	2	19	$\frac{5+2}{2}$	1·66	221
Ditto behind spandrills ...	2	19	2	2	152
Starlings (to top of parapet) ...	4	$\frac{0{\cdot}7854}{2} \times 3$	3	21·5	304
Wing walls	4	$\frac{3{\cdot}1416}{3} \times 14$	2	10	1,172
Ditto over abutment steps ...	4	2	2	3·5	56
Ditto ditto ditto ...	4	2	2	1·5	24
End pillars...	4	2·5	2·5	10	250
Arch	1	18	19	1·5	513
Spandrills	1	(18 × 3·5 − 36)		19	513
Parapet over arch and abutment...	2	22	1·5	3·5	231
Ditto over wing walls	4	$\frac{3{\cdot}1416}{3} \times 13{\cdot}25$	1·5	3·5	291
Dwarf pillars at ends	4	2	2	3·5	56
Total Masonry ...	...	...	...	...	8,018
Cut Stone-work.					
Coping of parapet	...	117	2·0	0·5	117
String course of ditto	...	117	1·0	0·5	58
Heads of abutments ...	2	28	1·0	0·5	28
Facing of arch	2	18	2·0	1·5	108
Total ...	...	...	...	...	311
Metalling.					
Over arch ... ... /	1	16	16	0·5	128
Between wing walls	1	17	$\frac{32+16}{2}$	0·5	204
Total ...	...	...	...	...	332
Earth-work.					
In approaches	2	$\frac{255}{2}$	$\frac{20+44}{2}$	8·5	69,360
Ditto in side ramps	4	$\frac{110}{2}$	$\frac{20+44}{2}$	5·5	38,720
Total ...	...	...	...	...	108,080

ABSTRACT.		Rs.
7,505	Cubic feet of masonry, at Rs. 15 per 100	1,125
513	Ditto arch, at Rs. 20 per 100	102
311	Ditto cut stone-work, at Rs. 300 per 100	93
108,080	Ditto earth-work, at Rs. 2-8 per 1,000	272
332	Ditto metalling, at Rs. 6 per 100	20
	Contingencies at 5 per cent.	80
	Total...Rs.	1,692
	amount used in general estimate for bridge of 1 span of 16 feet ... "	1,700

G. Design No. X.

	No.	L.	B.	D.	Total.
Masonry.					
Abutments up to top of tow-path..	2	19	6·5	8	1,976
Curtain walls	2	7	1·5	6	126
Curved ends to tow-paths ...	4	$\frac{3·1416}{2} \times 3·75$	2	8	376
Flooring	1	7	19	1·5	199
Abutments above tow-path ...	2	19	5	3·5	665
Ditto behind skew-backs	2	19	·75	$\frac{1·25}{2}$	36
Abutments to top	2	19	3·25	4	494
Starlings to top of parapets ...	4	$\frac{0·7854}{2} \times 3$	3	18·5	261
Wing walls	4	$\frac{3·1416}{3} \times 13$	2	9	980
Ditto over abutment steps ...	4	19	1	4	304
Ditto end pillar	4	2·5	2·5	11	275
Arch	1	11·7	19	1·5	333
Spandrill	1	11·8 × 2—15·7		19	150
Parapets over arch and abutment..	2	16	1·5	3·5	168
Ditto over wing walls... ...	4	$\frac{3·1416}{3} \times 12·75$	1·5	3·5	280
Dwarf pillars at corners	4	2	2	3·5	56
Total Masonry ...	...	...	...	...	6,679

	No.	L.	B.	D.	Total.
Cut Stone-work.					
Coping of parapets	...	100	2·0	0·5	100
String course of ditto	...	100	1·0	0·5	50
Heads of abutments ...	2	26·5	1·0	0·5	26
Facing of arch	2	15·75	2·0	1·5	95
Total Cut Stone-work ...	...	...	...	...	
Metalling.					
Over arch...	1	10	16	0·5	80
Between wing walls	2	15	$\frac{32+16}{2}$	0·5	360
Total Metalling ...	...	...	...	...	440
Earth-work.					
In approaches	2	$\frac{225}{2}$	$\frac{40+20}{2}$	7·5	50,625
Ditto side ramps	4	$\frac{100}{2}$	$\frac{40+20}{2}$	5	30,000
Total Earth-work ...	...	...	...	...	80,625

ABSTRACT.

			Rs.
80,625	Cubic feet of	earth-work, at Rs. 2-8 per 1,000	201
6,346	Ditto	masonry, at Rs. 15 per 100	952
333	Ditto	arch, at Rs. 20 per 100	67
271	Ditto	cut stone-work, at Rs. 30 per 100	81
440	Ditto	metalling, at Rs. 6 per 100	26
	Contingencies at 5 per cent.		66
		Total ...Rs.	1,393
	Amount used in general estimate for bridge of one span of 12 feet ... Rs.		1,400

H. Culverts in approaches, 4 feet water-way.

	No.	L.	B.	D.	Total.
Masonry.					
Body of culvert taken solid ...	1	65	8	4	2,080
Arch taken solid	1	65	·78 × 8	8 × 0·5	1,622
					3,702
Deduct—Hollow of body ...	1	65	4	2	520
Half ditto of arch ...	0·5	65	·78 × 4	4 × 0·5	203
					723
Total Masonry ...	...	...	...	...	2,979

ABSTRACT.

		Rs.
2,979	Cubic feet of masonry, at Rs. 15 per 100	447
	Contingencies at 5 per cent.	22
	Total ... Rs.	469
	Amount taken in general estimate ... Rs.	470

K. Culverts in approaches, 3 feet water-way.

	No.	L.	B.	D.	Total.
Masonry.					
Body of culvert taken solid ...	1	45	6	3	810
Arch taken solid	1	45	0·78 × 6	6 × 0·5	632
					1,442
Deduct—Hollow of body ...	1	45	3	1·5	202
Half ditto of arch ...	0·5	45	·78 × 3	3 × 0·5	79
					281
Total Masonry ...	...	...	...	...	1,161

ABSTRACT.

		Rs.
1,161	Cubic feet of masonry, at Rs. 15 per 100	174
	Contingencies at 5 per cent.	9
	Total ... Rs.	183
	Amount taken in general estimate ... Rs.	200

No. 14, Branch Heads.

A. Channels, Classes III. to VII.

Work required in addition to the Bridges.

	No.	L.	B.	D.	Total.
Masonry.					
Redan shaped steps sides... ...	2	54	$\frac{14+2}{2}$	7	6,048
Ditto angle solid	1	$\frac{\cdot7854\times3}{8}$	$\frac{24\times24}{3}$	7	33
Blocks under ditto	8	13 × 7 — 0 × 4		10	4,080
Wells at angle	3	$7854\times(8^2-5^2)$		10	919
					11,080
Deduct hollow under arches ...	2	54	3·5	$\frac{2+4}{2}$	...
					1,134
					9,946
Stairs	1	30	9	19 + 4·5	3,172
Parapets	2	30	1·5	3	270
					13,388
Deduct—					
First	1	12	4	9	432
Second	1	9	$\frac{4\cdot5}{2}$	9	182
Third	1	4·5	9	4	162
Fourth	1	6·5	9	$\frac{10\cdot5+7}{2}$	497
					1,271
Total Masonry, excluding flooring..	...	...	...	...	12,117
Wood-work.					
Class III. Beams	8	30	1	0·66	160
Boards 4 × 7	108	9	1	$\frac{1}{8}$	121
					281
Class IV. Beams	8	23	1	0·5	92
Boards 4 × 21	84	7·5	1	$\frac{5}{48}$	65
					157
Class V. Beams two arches ...	4	35	1	0·5	70
Boards 2 × 32	64	6·5	1	$\frac{1}{12}$	35
					105

	No.	L.	B.	D.	Total.
Class VI. Beams...	4	28	1	$\frac{6}{12}$	47
Boards 2 x 25	50	6	1	$\frac{1}{12}$	25
					72
Class VII. Beams	4	22·5	1	$\frac{5}{12}$	37
Boards...	40	5	1	$\frac{1}{16}$	12
					49

	Flooring.					Dry Stone-work.				
	No.	L.	B.	D.	Total.	No.	L.	B.	D	Total.
Class III.	2	53	25	2	5,300	2	68	15	3	6,120
IV.	2	40	22	2	3,520	2	52	15	3	4,680
V.	2	26	2	2	2,288	2	36	15	3	3,240
VI.	2	19	22	2	1,672	2	27	15	2·5	2,025
VII.	2	14	22	2	1,232	2	20	15	2	1,200

ABSTRACT.

			Rs.
III. 12,117	Cubic feet of	masonry, at Rs. 15 per 100 cubic feet... ...	1,817
5,300	Ditto	flooring, at Rs. 15 per 100 cubic feet	795
6,120	Ditto	dry stone-work, at Rs. per 100 cubic feet ...	490
281	Ditto	wood work, at Rs. 3 per foot...	843
	Blocks and Tackling	... ...	50
	Contingencies at 5 per cent.	... ...	199
		Total ... Rs.	4,194
IV. 12,117	Cubic feet of	masonry, at Rs. 15 per 100 cubic feet	1,817
3,520	Ditto	flooring, at Rs. 15 per 100 cubic feet	528
4,680	Ditto	dry stone-work, at Rs. 8 per 100 cubic feet ...	374
157	Ditto	wood-work, at Rs. 3 per foot	471
	Blocks and Tackling	... ...	50
	Contingencies at 5 per cent.	... ...	130
		Total ... Rs.	3,370
V. 12,117	Cubic feet of	masonry, at Rs. 15 per 100 cubic feet	1,817
2,288	Ditto	flooring, at Rs. 15 per 100 cubic feet	343
3,240	Ditto	dry stone-work, at Rs. 8 per 100 cubic feet ...	259
105	Ditto	wood work, at Rs. 3 per foot...	315
	Blocks and Tackling	... ...	50
	Contingencies at 5 per cent.	... ...	131
		Total ... Rs.	2,915

VI.	12,117	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	1,817
	1,672	Ditto flooring, at Rs. 15 per 100 cubic feet	251
	2,025	Ditto dry stone-work, at Rs. 8 per 100 cubic feet ...	162
	72	Ditto wood-work, at Rs. 3 per foot	216
		Blocks and Tackling	50
		Contingencies at 5 per cent.	124
		Total ... Rs.	2,620
VII.	12,117	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	1,817
	1,232	Ditto flooring, at Rs. 15 per 100 cubic feet	185
	1,200	Ditto dry stone-work, at Rs. 8 per 100 cubic feet ...	96
	49	Ditto wood-work, at Rs. 3 per foot	147
		Blocks and Tackling	50
		Contingencies at 5 per cent.	115
		Total ... Rs.	2,410

B. Branch heads for Channels, Classes VIII. to X.

	No.	L.	B.	D.	Total.
Masonry. Redan shaped walls, Class VIII. ...	2	50	3	8	2,400
Ditto Class IX.	2	45	2·5	7	1,575
Ditto Class X.	2	40	2	6	960
Wood-work. Class VIII.					
Beams	4	18	0·5	0·33	12
Planks (2 x 16)	32	4	1	$\frac{1}{16}$	8
Total Wood-work of 8th class...	...	...	...	...	20
Class IX.					
Beams	4	13·5	$\frac{3}{8}$	·33	6·75
Planks (2 x 12)	24	13·5	1	$\frac{1}{16}$	4·66
Total	...	...	...	...	1[illegible]·41
Class X.					
Beams	4	8	·33	·25	2·66
Planks	14	3	1	$\frac{1}{24}$	1·75
Total	...	...	...	...	4·41
Dry Stone-work. Class VIII.	2	25	15	2	1,500
Class IX.	2	20	12	2	960
Class X.	2	12	10	1·5	360

ABSTRACT.

	Class VIII.		Class IX.		Class X.	
	Quantity.	Rupees.	Quantity.	Rupees.	Quantity.	Rupees.
Masonry, at Rs. 15 per 100 cubic feet	2,400	360	1,575	236	960	144
Dry Stone-work, at Rs. 8 per 100	1,500	120	960	77	360	29
Wood-work, at Rs. 3 per foot ...	20	60	11·41	35	4·41	14
Contingencies at 5 per cent.	...	27	...	17	...	9
Total Rs. ...	...	567	...	365	...	196

No. 15, Distributaries (See Plate XXI.)

A. Channel Head.

	No.	L.	B.	D.	Total.
Masonry.					
Foundation walls below flooring...	2	32	2	3·5	448
Ditto ditto ...	2	6	2	3·5	84
Flooring over all	1	32	10	1·5	480
Side walls, 1st	2	30	2	1·5	182
Ditto 2nd	2	26	2	1·5	156
Ditto 3rd	2	22	2	1·5	132
Ditto 4th	2	18	2	1·5	108
Arch and covering, taken solid to spring	1	19	6	3·5	399
Cross walls, front	1	6	3·5	6	126
Ditto rear	1	6	1·5	6	54
Parapets	2	10	1·5	3	90
Total Masonry ...	...	...	...	...	2,259
A sluice board with gear... ...	1	6	2·5	0·125	2
Metalling, say	1	20	16	0·5	160

ABSTRACT.

		Rs.
2,259	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	339
160	Ditto metalling, at Rs. 6 per 100 cubic feet	10
2	Sluice board and gear	25
	Contingencies at 5 per cent.	19
	Total cost for one Channel head ... Rs.	393

B. Channels (per mile.)

	No.	L.	B.	D.	Total.
Earth-work.			Mean.		
Channel, 1 mile	1	5,280	10	4	211,200

ABSTRACT.

		Rs.
211,200	Cubic feet of earth-work, at Rs. 1-8 per 1,000 cubic feet	317
	Contingencies at 5 per cent.	16
	Total cost per mile of Channel ... Rs.	333

C. Falls.

	No.	L.	B.	D.	Total.
Masonry.					
Floor of well	1	20 × ·7854	20	2	628
Walls of ditto (taking the tail steps as agreed to completing the circle)	1	22½ × 3·1416	2·5	14·5	2,533
Front curtain wall	1	20	2	3	120
Wing walls, upper	2	10·25 × 3·1416 × 0·25 × 1·5		7	173
Flooring between ditto	1	8	$\frac{20+8}{2}$	1·5	168
Bridge abutment walls	2	11	2·5	2	110
Ditto all between spring of arch and upper floor, solid	1	12	11	3·5	462
Ditto foundation of abutment ...	2	11	2·5	3	165
Ditto curtain wall	1	7	1·5	3	31
Flooring	1	11	7	1·5	115
Wing wall, straight	2	5	2	10	200
Ditto end	2	7 × 3·1416 × ·25 × 2		8	176
Parapets over bridge	2	11	2	2·5	110
Total Masonry ...	...	...	...	......	4,991
Excavation...	1	24 × ·7854	24	14·5	6,559

ABSTRACT.

		Rs.
4,991	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	748
6,559	Ditto of earth-work, at Rs. 4 per 1,000 cubic feet	26
	Contingencies at 5 per cent.	39
	Total cost... Rs.	813

D. Metalled Fords.

	Rs.
Excavation of 2 ramps, 40 × 30 × 4 × 0·5 = 4,800 cubic feet, at Rs. 1-8 per 1,000	7
Metalling, 30 × 40 × 0·75 = 900 cubic feet, at Rs. 6 per 100 cubic feet	54
Fencing 100 feet of jungle wood fence, at 4 annas a foot...	25
Contingencies at 5 per cent.	4
Total ... Rs.	90

E. Bridges.

	No.	L.	B.	D.	Total.
Masonry.					
Body of bridge taken solid ...	1	19	13	8·5	2,099
Deduct Hollow under flooring ...	1 1	16 19	6 7	2 2	192 266 — 458
					1,641
Wing wall	4	4	2	5·5	176
Ditto	4	5	2	2	80
Parapets	2	13	1·5	2·5	97
Ditto	4	9	1·5	2·5	135
					488
Total Masonry ...	...	...	...	...	2,129

ABSTRACT.

		Rs.
2,129	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	319
	Contingencies, at 5 per cent.	16
	Total for a bridge ... Rs.	335

F. Escapes.

	No.	L.	B.	D.	Total.
Masonry.					
Side wall below flooring, straight.	2	9	2·5	3	135
Ditto ditto curved ...	4	4·75 × 3·14	2·5	3	450
Curtain wall	2	15	1·5	3	135
Flooring	1	10	8·5	1·5	127
Ditto	1	12	8	2	192
Ditto over lap	1	7	2	0·5	7
Abutment wall	2	3	2·5	5	75
Bridge, solid, above spring ...	1	7	3	3	63
Straight wall below bridges ...	2	6	3·5	5	210
Ditto steps	2	6	2·5	1	30
Wing Walls	4	4·75 × 3·14	2·5	5	745
Total Masonry ..	...	...	...	...	2,169
Dry Stone with piles ...	1	15	8	2	240
Total ...	...	...	...	...	240

ABSTRACT.

			Rs.
2,169	Cubic feet of masonry, at Rs. 15 per 100 cubic feet ...	...	325
240	Ditto of dry stone-work, at Rs. 8 per 100 cubic feet...	...	19
	Contingencies	...	17
	Total for an Escape...	Rs.	361

G. Aqueduct.

	No.	L.	B.	D.	Total.
Mosonry.					
Foundation abutment of piers ...	4	17	5	2	680
Ditto ditto ...	2	17	4·5	2	306
Ditto ditto ...	2	17	4	2	272
Curtain walls	6	8	2	2	192
Ditto	6	9	2	2	216
Flooring under bridge	3	9	7	1·5	283
Abutment to spring	2	11	4	5	440
Ditto behind skew-back	2	11	3·5	1	77
Ditto spandrill	2	11	3	4·5	297
Piers to spring	2	11	3	5	330
Ditto	2	11	2	1	44
Ditto	8	3	$3 \times 0·66$	5	238
Corpets ditto	8	3	$3 \times 0·33$	1	24
Arches	3	12	7	1·5	378
Spandrills	3	$(11 \times 4·5 - 21·5)$		7	588
Over peer between spandrills ...	2	11	1	3·5	77
Wing walls, straight	4	7	2	11·5	644
Ditto ditto	4	4	2	6·5	208
Ditto curved	4	$\frac{7 \times 3·14}{2}$	2	3·5	308
Curtain wall of aqueduct ...	2	15	2	3	180
Flooring in wings	2	11	7	1·5	231
Ditto	2	6	10	1·5	180
Parapets	2	66	2	2·5	660
Ditto	2	$\frac{7 \times 3·14}{2}$	2	2·5	110
Total Masonry ...	...	......	.....	......	6,963
Excavation	1	11	5	66	3,630

ABSTRACT.

			Rs.
3,630	Cubic feet of earth-work, at Rs. 4 per 1,000 cubic feet ...	...	14
6,963	Ditto of masonry, at Rs. 15 per 100 cubic feet ...	...	1,044
	Contingencies at 5 per cent.	...	53
	Total for Aqueduct	... Rs.	1,111

H. Syphon Drains.

	No.	L.	B.	D.	Total.
Masonry.					
Wing walls, lower channel curved.	4	$7 \times \frac{3 \cdot 14}{2}$	2	6	527
Ditto ditto straight	4	4	2	6	192
Ditto ditto ditto	4	7	2	8·5	476
Steps, lower channel	2	7	3	3	126
Ditto	2	7	1	2	28
Ditto	2	7	3	3·5	147
Ditto	2	7	1	1	14
Ditto	2	7	2	2·5	70
Flooring of lower channel ...	1	15	7	1·5	157
Abutments of arch	2	11	2	4·5	198
Arch to floor taken solid	1	11	10	3·5	385
Parapet walls over arch	2	11	2	2·5	110
Wing walls of upper channel ...	4	6	2	5	240
Ditto curved parts	4	$7 \times \frac{3 \cdot 14}{2}$	2	5	439
Flooring	2	5	7	1	70
Curtain walls	2	7	1·5	2·5	52
Total Masonry ...	......	.. ...	......	... ...	3,231
Excavation.					
Say	1	33	7	5·5	1,270
And	4	11	2	3	264
Also	4	17	2	2·5	340
					1,874

ABSTRACT.

		Rs.
3,231	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	485
1,874	Ditto of earth-work, at Rs. 2 per 1,000 cubic feet	4
	Contingencies at 5 per cent.	24
	Total ... Rs.	513

K. *Village Water-course head, or Module.*

(Hindustani "Pymana.")

	No.	L.	B.	D.	Total.
Masonry.					
Long walls...	2	17·5	1	2·5	87·5
Ditto above	2	$\frac{15{\cdot}5+11{\cdot}5}{2}$	1	3	81·0
Curtain walls	2	2·5	1	1·5	7·5
Flooring	1	15	2·5	0·5	18·75
Cross walls, front	1	2·5	1·5	4·5	16·9
Ditto rear	1	2·5	1	4·5	11·25
Total Masonry ...	...	...	...	...	223
Stone-work.					
Groove	2	3	1	1	6
Slab	1	2	2	0·5	2
Inlets	1	2	1·5	0·33	1
Ditto	1	2	1	0·33	0·66
Road-way slabs	1	5	4·5	0·5	11·25
Total Stone-work ...	...	...	...	...	21

ABSTRACT.

		Rs.
223	Cubic feet of masonry, at Rs. 15 per 100 cubic feet	33
21	Ditto of stone-work, at Rs. 50 per 100 cubic feet	10
1	Sluice plank	2
	Contingencies at 5 per cent.	2
	Total ... Rs.	47

GENERAL ABSTRACT FOR ONE MILE OF DISTRIBUTARY.

In each mile.		
Earth-work	...	333
One Ford	...	90
Six village water-course heads	...	282
Total in each mile	...	705
In ten miles.		
Two heads	786	
Two falls	1,626	
One escape	361	
One aqueduct	1,111	
One syphon drain	513	
One bridge	335	
One tail fall, same cost as head	393	
Total	5,125	
Of which one-tenth is		512
Total cost per mile	...	1,217

This estimate is only intended to show how the cost may possibly be made up. In practice it has been found in the Ganges Canal Works that the Rajbuhas or Distributaries cost about Rs. 1,000 per mile; and Rs. 1,200 seems a fair amount to assume for the Soane Canals.

The land at 50 feet width will come to about 6 acres, a little short of 10 beegahs per square mile, which at the average rate assumed will cost Rs. 60, and Rs. 40 more may be added for clearing, fencing, &c.; so that on the whole I take the cost of Distributaries or Rajbuhas at Rs. 1,300 per mile.

No. 16.

ACCOUNT OF THE EXPENDITURE ON THE PRELIMINARY SURVEY OF THE SOANE CANALS AND OTHER IRRIGATION PROJECTS FOR SHAHABAD AND BEHAR.

First Survey of 1854-55.			Rs. A. P.
		Rs. A. P.	
Salary of Superintendent, 6 months, at Rs. 500 ...		3,000 0 0	
Salaries of Native Levellers, Writers and Draftsmen ...		1,330 13 11	
Wear and tear of instruments		746 11 5	
			5,077 9 4
Operations from December 1855 *to March* 1858.			
Salaries of all classes		28,669 8 0	
Travelling allowances		3,398 0 0	
Contingent charges		670 12 10	
Wear and tear of instruments		324 2 7	
Loss of instruments in the mutinies		1,639 14 2	
Construction and repair of bungalows for the shelter of the Establishment at various spots		11,406 9 8	
			46,108 15 3
Small Establishment kept up from March 1858 to December 1860 ...			3,174 14 1
From December 1860 *to August* 1861.			
Salaries		12,730 4 5	
Travelling allowances		458 3 0	
Contingent charges		602 10 4	
Printing Plans	1,410 8 0		
Printing Report and Estimates...	1,002 5 9		
		2,412 13 9	
			16,203 15 6
		Grand total Rs.	70,565 6 2

GENERAL ESTIMATE.

I have not thought it necessary to print the calculations upon which the following details are based. The reader who is so inclined will have no difficulty in following most of the details set down, being guided by the Report and the several detailed Estimates in the Appendix. It only appears necessary to explain that the number of bridges is fixed at 3 per mile, or rather more, but in this calculation the bridges at the locks and falls are counted; so that a canal of 24 miles long having 5 locks and falls would have 3 bridges in addition, making 8 points of cross communication. The falls are of course given in accordance with the Sections for the lines of which the levels have been taken. For the remaining lines they are taken from a calculation of the excess of the total fall of the country over that intended to be given to the canal bed, the former being taken from the sketched contours on Plate III.

Head Works.

		Rs.	Rs.
Land, 800 beegahs, at Rs. 6	4,800		
Plantations, one-sixth cost of land	800		
Roads and fences, say 10 miles, at Rs. 300	3,000		
		8,600	
Temporary quarters, 1 Superintending Engineer, 1 Executive, 3 Assistants, 15 Subordinates and Clerks; plus one-fourth		14,750	
Western lock channel head		1,33,973	
Eastern ditto		60,151	
Temporary dam		2,24,469	
Workshops		50,000	
Permanent quarters		62,000	
Ditto dam		11,29,269	
Western Canal head bridge		1,46,346	
Eastern ditto		34,462	
Rails, rolling stock, and other plant		2,50,000	
			21,14,020
Establishment at 12½ per cent.			2,64,252
			23,78,272
30 per cent. added to cover probable rise of prices			6,34,206
Total estimated outlay ...			30,12,478

Western Canal, Main Line (A).

10½ miles long, with 5 miles of escape; width at bottom 73 feet; depth of water 7½ feet; fall of bed per mile 0·75 foot; discharge 1,980 cubic feet per second.

		Rs.
Land, 7 miles at Rs. 845		5,915
Land, 8¼ miles at Rs. 563		4,645
Plantations, one-sixth cost of land		1,760
Roads and fences, 15¼ miles at Rs. 400		6,100
Excavation		5,73,381
5 Inlets of 10 feet water-way with drop ...	20,000	
2 Ditto 20 ditto ditto ...	10,400	
Tootla drainage works	3,10,980	
		3,41,380
2 Bridges over deep cutting ...	53,000	
4 Ordinary bridges	76,000	
		1,29,000
Escape head, 8 openings	14,000	
4 Falls of 100 feet water-way on escape to bring it to the level of the Soane, which provide sufficient cross communication	1,40,000	
		1,54,000
Carried over		12,16,181

	Rs.
Brought forward...	13,16,181
10 Miles of Distributaries, at Rs. 1,300 per mile ...	13,000
1 First Class Chokee, Rs. 2,000; one Second Class Chokee, Rs. 800; 1 Assistant Engineer's Rs. 5,250, and three Overseers' quarters Rs. 7,875 ...	15,925
	12,45,106
Establishment at 12½ per cent. ...	1,55,638
	14,00,744
30 per cent. added	3,73,532
Total	17,74,276

Arrah Branch, upper (B).

22 miles in length with 1¼ miles of escape; width at bottom 42½ feet; depth of water 5½ feet; fall of bed per mile 1·04 feet; discharge 877 cubic feet per second.

	Rs.	Rs.
Land for 23½ miles of Canal, at Rs. 422 per mile	9,917	
Ditto 32 beegahs for Executive Engineer's Head Quarters	192	
Ditto for six locks	6,912	
		17,021
Plantations, one-sixth cost of land		2,670
Roads and Fences, 23½ miles at Rs. 250		5,875
Excavation...		1,75,151
1 Syphon drain for the Nowadeeh Nala... ...		50,000
1 Bridge at head, Class III., with regulating apparatus	16,100	
1½ Bridges, to cover cost of one larger bridge on Grand Trunk Road...	21,000	
8 Four feet culverts under approaches to bridges ...	3,760	
		40,860
Escape head, of 6 openings	12,500	
2 Falls of 60 feet water-way (to bring escape to level of the Soane) at	40,000	
		52,500
6 Falls with barrier bridges, double locks, and navigable channels ... Irrigation		1,62,000
Navigation		2,73,600
100 Miles of distributaries at Rs. 1,300 per mile, for an irrigation area of 148 square miles		1,30,000
6 Mills of two houses each, at Rs. 2,200		13,200
2 First Class Chokees, Rs. 4,000; 6 Second Class ditto Rs. 4,800, 5 Overseers' quarters Rs. 13,125, including both temporary and permanent	21,925	
Quarters for Executive Engineer and Office; and workshops, including permanent and temporary quarters	25,750	
		47,675
Carried over		9,70,5[illegible]2

		Rs.
	Brought forward	9,70,552
Establishment at 12½ per cent.		1,21,319
		10,91,871
30 per cent. added to meet rise of prices ...		2,91,166
	Total	13,83,037

Arrah Branch, second portion (C).

7½ miles, with 4 miles of escape; width at bottom 31 feet; depth of water 4¾ feet; fall per mile 1·25 feet; discharge, 576 cubic feet per second.

Land for 11½ miles of canal at Rs. 282	3,243
Plantations	540
Roads and Fences at Rs. 250 per mile	2,875
Excavation	62,093
1 Inlet on level, of 20 feet water-way	3,000
1 Escape 30 ditto	6,500
2¼ Bridges, Class IV., (the ¼ to allow for district road) ...	22,500
4 Four feet culverts in approaches to bridges	1,880
Regulating gear for head bridge	1,685
Escape dam, 4 openings	7,750
1 Fall of 40 feet water-way on escape	11,500
2 Locks with double chambers and waste weirs, at ... ... Irrigation ...	31,000
Navigation ...	59,800
2 Mills of 2 houses each, at Rs. 2,200	4,400
24 Miles of distributary, at Rs. 1,300 per mile for 35 square miles of area	31,200
1 First Class and 2 Second Class Chokees, and one Overseers quarters	5,425
	2,55,391
Establishment at 12½ per cent.	31,923
	2,87,314
30 per cent. added to cover rise in prices	76,617
Total	3,63,931

Arrah Branch, third part (D).

Length of Canal 15½ miles, with two miles of escape; width at bottom 28 feet; depth of water 3¾ feet; fall per mile 1·54 feet; discharge 335 cubic feet per second.

	Rs.
Land 17½ miles at Rs. 255 per mile	4,462
Plantations	737
Carried over ...	5,199

			Rs.
	Brought forward ...		5,199
	Roads and Fences at Rs. 250 per mile		4,375
	Excavation		63,277
2	Inlets of 20 feet opening on level	6,000	
3	Escapes 30 ditto	19,500	
			25,500
1	Inlet of 100 feet	7,000	
1	Escape of 150 feet	14,250	
			21,250
3	Bridges, Class V., including one with regulating gear at head ...		28,500
6	Four feet culverts in approaches to bridges		
2	Falls of 30 feet water-way on escape		15,000
3	Double locks { Irrigation		22,500
	{ Navigation		91,500
3	Sets of Mills, at Rs. 2,200		6,600
42	Miles of Distributary, at Rs. 1,300 per mile, for 62 square miles of area to be irrigated		54,600
1	First and 3 second Class Chokees, and residence for one Overseer ...		7,025
			3,45,326
	Establishment at 12½ per cent. ...		43,166
			3,88,492
	30 per cent. added as before		1,03,598
	Total		4,92,090

Arrah Branch, last part (E).

20½ miles in length, including tail escape; width at bottom 18½ feet; depth of water 3½ feet; fall per mile 1·75 feet; discharge Rs. 243 cubic feet per second.

		Rs.
	Land for 20½ miles at Rs. 231	4,375
	Plantations	725
	Roads and Fences, at Rs. 250 per mile	5,125
	Excavation	35,181
3½	Bridges, Class VI., one with regulating apparatus	27,350
6	Four feet culverts in approaches to bridges	2,820
5	Single locks, including tail lock { Irrigation	27,500
	{ Navigation	1,10,000
	Possible addition for navigation in the Banas	1,50,000
5	Sets of Mills, at Rs. 2,200 each	11,000
80	Miles of Distributaries, at Rs. 1,300 per mile, for 123 square miles of irrigated area	1,04,000
	Carried over	4,78,076

		Rs.
Brought forward	...	4,78,076
2 First Class and 3 Second Class Chokees, and residences for 1 Assistant Engineer and two Overseers	...	16,900
		4,94,976
Establishment at 12½ per cent.		61,872
		5,56,848
30 per cent. added as before...		1,48,493
Total	Rs.	7,05,341

Nansaugor Branch (F).

22½ miles long, including tail escape; width at bottom 8 feet; depth of water 1¾ feet; fall per mile 2 feet; discharge 45 cubic feet per second.

			Rs.
Land, 22½ miles at Rs. 127½	2,869		
Plantations	477		
Roads and Fences, at Rs. 150	3,375		
			6,721
Excavation		...	29,744
2 Falls of 10 feet water-way, including tail fall ...		...	4,000
4 Bridges, Class IX., at Rs. 1,700, three with regulating apparatus	7,895		
8 Three feet culverts in approaches to bridges... ...	1,600		
18 Metalled Fords, at Rs. 150 each...	2,700		
			12,195
1 First Class and 2 Second Class Chokees		...	3,600
1 Mill		...	1,300
16 Miles of Distributary, at Rs. 1,300 a mile, will suffice, with the canal here, to complete the distribution of water	20,800		
Modules for village water-course heads, for 22 miles of Canal at Rs. 400 per mile	8,800		
Total		...	87,160
Add 12½ per cent. for Establishment ...		...	10,895
			98,055
Add 30 per cent. as before		...	26,148
Total		... Rs.	1,24,203

Peeroo Branch, first part (G).

11½ miles in length, with 6 miles of escape; width at bottom 17 feet; depth of water 3·1 feet; fall per mile 1·8 feet; discharge 214 cubic feet per second.

		Rs.
	Land	4,042
	Plantations	673
	Roads and Fences	4,375
	Excavation	45,018
	One fall 25 feet water-way on escape	5,500
3	Bridges, Class VI., one with regulating apparatus	26,600
6	Three feet culverts in approaches to bridges	1,200
1	Escape head of 30 feet water-way	5,000
2	Locks of 60 × 10 at Rs. 6,500 { Irrigation	11,000
	{ Navigation...	2,000
53	Miles of Distributary at Rs. 1,300 a mile, for 77 square miles of area to be irrigated...	68,900
2	Mills (single house) at Rs. 1,300 each	2,600
1	First and 1 Second Class Chokee, 1 Assistant Engineer's and 1 Overseer's residence	10,675
		1,87,583
	Establishment at 12½ per cent. ...	23,448
		2,11,031
	30 per cent. added as before	56,274
	Total cost ... Rs.	2,67,305

Peeroo Branch, second part (H).

17½ miles in length, including tail escape; width at bottom 11 feet; depth of water 2½ feet; fall per mile 2 feet; discharge 84 cubic feet per second.

	Land, 17½ miles	3,360
	Plantations	560
	Roads and Fences	2,625
	Excavation	17,949
	One fall 20 feet water-way at tail	4,000
2	Bridges, Class VIII., one with regulator	5,167
4	Three feet culverts in approaches to bridges...	800
4	Locks 60 × 10 at Rs. 6,500 each ... { Irrigation	16,000
	{ Navigation	10,000
72	Miles of Distributary, at Rs. 1,300 per mile, for 110 square miles of area to be irrigated	93,600
4	Mills at Rs. 1,300 each	5,200
1	First and 1 Second Class Chokee, and 1 Overseer's residence ...	5,425
		1,63,886
	Estalishment at 12½ per cent. ...	20,486
		1,84,372
	30 per cent. added as before ...	49,166
	Total cost Rs.	2,33,538

Jugdispoor Branch (I).

17 Miles in length to tail escape on the Charyee; 10½ feet wide at bottom; depth of water 2·2 feet; fall per mile 2 feet; discharge 73 feet per second.

	Rs.
Land at Rs. 166 per mile	2,822
Plantations	470
Roads and fences	2,550
Excavation	16,965
1 Bridge, Class VIII., with regulator...	2,867
2 Three feet culverts in approaches to bridge	400
1 Fall of 20 feet water-way at tail	4,000
6 Locks of 60 × 10 at Rs. 6,500 each { Irrigation	24,000
{ Navigation	15,000
64 Miles of Distributary, at Rs. 1,300 per mile, for 97 square mile of area to be irrigated	83,200
6 Mills (one house each) at Rs. 1,300	7,800
1 First and 1 Second Class Chokee, and one Overseer's residence ...	5,425
	1,65,499
12½ per cent. for Establishment ...	20,687
	1,86,186
30 per cent. added as before	49,649
Total	2,35,835

Raneepoor Branch, upper part (J).

22 miles in length, with 2 miles escape; width at bottom 16 feet; depth of water 3 feet; fall per mile 1·9 feet; discharge 190 cubic feet per second.

	Rs.
Land at Rs. 192 a mile, 24 miles	4,608
Plantations	768
Roads and fences	3,600
Excavation	49,363
1 Escape head, 30 feet water-way	4,000
1 Fall at escape tail, 25 feet water-way	5,500
6 Bridges, Class VII., one with regulator	38,400
12 Three feet culverts in approaches to bridges	2,400
2 Locks of 60 × 10 at Rs. 6,500 each { Irrigation	11,000
{ Navigation	2,000
2 Mills, single house, at Rs. 1,300	2,600
74 Miles of Distributary, at Rs. 1,300 per mile, for 111 square miles of area to be irrigated ..	96,200
Carried over ...	2,20,439

	Brought forward ...	2,20,439
2 First Class and 2 Second Class Chokees, one Assistant Engineer's residence		10,850
		2,31,289
	Establishment at 12½ per cent.	28,911
		2,60,200
	Add 30 per cent. as before	69,387
	Total	3,29,587

Raneepoor Branch, lower part (K).

Length 13½ miles, including tail escape; width at bottom 12¾ feet; depth of water 2¾ feet; fall per mile 2 feet; discharge 106 cubic feet per second.

	Rs.
Land, 13½ miles at Rs. 192	2,592
Plantations	432
Roads and fences	2,025
Excavation	15,072
4 Bridges, Class VII., one with regulator...	26,400
6 Three feet culverts in approaches to bridges	1,200
95 Miles of Distributary, at Rs. 1,300 per mile for 141 square miles of irrigation	1,23,500
1 First and 1 Second Class Chokee	2,800
	1,74,021
Establishment at 12½ per cent.	21,752
	1,95,773
Add 30 per cent. as before	52,206
Total	2,47,979

Sasseram Branch, upper part (L).

Length 7½ miles, with ½ mile escape; width at bottom 49 feet; depth of water 6 feet; fall per mile 1 foot; discharge 1,091 cubic feet per second.

		Rs.
Land, 8 miles at Rs. 422		
Ditto for Executive Engineer's Head Quarters	192	
Ditto for one Lock Channel	1,152	
		4,720
Plantations		786
Roads and fences at Rs. 400		3,200
Excavation		1,21,956

Carried over ...

Brought forward ...		1,30,662
Inlet and Escape head, 9 openings		20,500
Minor drainage works		27,000
Passage of the River Kao		3,20,000
Diversion of the Grand Trunk Road		17,000
2 Bridges, Class II., one with regulator		37,000
4 Four feet culverts in approaches to bridges		1,880
1 Fall with barrier bridge, double locks, and lock channel ...	Irrigation	35,000
	Navigation	42,300
20 Miles of Distributary, Rs. 1,300 per mile		26,000
1 First Class and 1 Second Class Chokee, accommodation for Executive Engineer and Office, and work-shops... ...		33,800
		6,91,142
Establishment at 12½ per cent.		86,393
		7,77,535
30 per cent. added as before		2,07,342
		9,84,877

Sasseram Branch, second part (M).

Length 22 miles, with one mile of escape; width at bottom 20 feet; depth of water 3½ feet; fall per mile 1·64 feet; discharge 288 cubic feet per second.

		Rs.
Land, 23 miles at Rs. 231		5,313
Plantations		885
Roads and Fences, at Rs. 250		5,750
Excavation		63,606
3 Inlets, 10 feet with drop		12,000
2 Bridges, Class VI., one including regulator...		18,600
4 Four feet culverts in approaches to bridges...		1,880
1 Escape head, 30 feet water-way		5,000
3 Falls, at tail of escape, 30 feet water-way		22,500
4 Single locks 120 x 16 with single waste weirs	Irrigation ...	30,000
	Navigation ...	80,000
2 Small locks 60 x 10, with two 12 feet waste weirs at Rs. 9,000	Irrigation ...	15,000
	Navigation ...	3,000
4 Mills (double) at Rs. 2,200 each		8,800
2 Ditto single at Rs. 1,300		2,600
60 Miles of Distributary, at Rs. 1,300 per mile for 88 miles area to be irrigated		78,000
Carried over		3,52,934

	Rs.
Brought forward ...	3,52,934
1 First and 5 Second Class Chokees, 1 Assistant Engineer's and 2 Overseers' residences	16,500
	3,69,435
Establishment at 12½ per cent.	46,179
	4,15,614
30 per cent. added as before	1,10,830
Total ...	5,26,443

Sasseram Branch, last part (N).

Length 18½ miles, including tail escape; width at bottom 10½ feet; depth of water 2½ feet; fall per mile 2 feet; discharge 72 cubic feet per second.

	Rs.
Land, 18½ miles, at Rs. 166 per mile	3,071
Plantations	512
Roads and Fences, at Rs. 150	2,775
Excavation	18,461
1 Fall at tail, 20 feet water-way	4,000
4 Bridges, Class VIII., one with regulator	9,767
8 Three feet culverts in approaches to bridges	1,600
2 Locks 60 × 10, at Rs. 6,500 { Irrigation	8,000
Navigation	5,000
2 Single Mills, at Rs. 1,300	2,600
64 Miles of Distributary, at Rs. 1,300 per mile, for 95 square miles of area to be irrigated	83,200
1 First and 2 Second Class Chokees	2,800
	1,41,786
Establishment at 12½ per cent....	17,723
	1,59,509
Add 30 per cent. as before ...	42,535
Total	2,02,044

Jugjeewun Branch, first part (O).

Length 17½ miles, with 2 miles of escape; width at bottom 14 feet; depth of water 2½ feet; fall per mile 2 feet; discharge 122 cubic feet per second.

	Rs.
Land, 19½ miles at Rs. 192	3,744
Plantations	624
Roads and Fences, at Rs. 150	2,925
Carried over	7,293

		Rs.
Brought forward ...		7,293
Excavation ...		37,080
Escape head, 30 feet water-way ...		4,000
Fall at tail, 25 ditto ...		5,500
2 Bridges, Class VII., one with regulator ...		14,400
4 Three feet culverts in approaches to bridges ...		800
5 Lock[illegible]0 × 10, at Rs. 6,500 { Irrigation ...		27,500
{ Navigation ...		5.000
5 Single Mills, at Rs. 1,300 ...		6,500
54 Miles of Distributary, at Rs. 1,300 per mile, for 81 square miles of area to be irrigated ...		70,200
1 First and 1 Second Class Chokee ...		2,800
		1,81,070
Establishment at 12½ per cent.		22,634
		2,03,704
Add 30 per cent. as before		54,321
Total		2,58,025

Jugjeewun Branch, second part (P).

Length 15 miles, including tail escape; width at bottom 9½ feet; depth of water $2\frac{1}{10}$ feet; fall per mile 2 feet; discharge 61 cubic feet per second.

		Rs.
Land, 15 miles at Rs. 166 ...		2,490
Plantations ...		415
Roads and Fences, at Rs. 150 ...		2,250
Excavation ...		14,131
3 Falls, one at tail, 115 feet water-way ...		9,000
2 Bridges (one with regulator), Class IX. ...	3,765	
4 Three feet culverts in approaches to bridges ...	800	
2 Metalled Fords, at Rs. 150 each ...	300	
		4,865
2 Single Mills, at Rs. 1,300 each ...		2,600
40 Miles of Distributary, at Rs. 1,300 per mile for 82 square miles of area to be irrigated in addition to the Canal which will be so used		52,000
Modules to be supplied to 15 miles of canal, at Rs. 400 per mile ...		6,000
1 First and 1 Second Class Chokee, and 1 Overseer's residence ...		5,425
		93,757
Establishment at 12½ per cent.		11,719
		1,05,476
Add 30 per cent. as before		28,127
Total		1,33,603

Buxar Branch, first part (Q).

Length 8 miles, with 7 miles escape; width at bottom 37 feet; depth of water 4¾ feet; fall per mile 1·18 feet; discharge 669 cubic feet per second.

		Rs.
Land, 15 miles at Rs. 422	6,330	
Ditto for 4 lock channels at Rs. 1,152 each	4,608	
		10,938
Plantations		1,623
Roads and Fences, at Rs. 250		3,750
Excavation		94,490
Escape head, 50 feet water-way		11,000
1 Fall at escape tail, 50 feet water-way		15,500
3 Bridges, one with regulator, Class IV.		33,370
6 Four feet culverts in approaches to bridges ...		2,820
4 Falls with double locks, &c. { Irrigation ...		80,000
{ Navigation ...		1,77,600
4 Mills (double), at Rs. 2,200 each		8,800
28 Miles of Distributary, at Rs. 1,300 per mile, for 42 square miles		36,400
1 First Class and 4 Second Class Chokees, and 1 Overseer's residence		7,825
		4,84,116
Establishment at 12½ per cent. as before		60,514
		5,44,630
Add 30 per cent. as before ..		1,45,235
Total ...		6,89,865

Buxar Branch, second part (R).

Length 11 miles, with 4 miles of escape; width at bottom 18½ feet; depth of water 3½ feet; fall per mile 1¾ feet; discharge 243 cubic feet per second.

	Rs.
Land, 15 miles at Rs. 231	3,465
Plantations	577
Roads and Fences, at Rs. 250	3,750
Excavation	40,581
Escape head, 30 feet water-way	5,000
Fall in tail of escape, 30 feet water-way	7,500
3 Bridges, Class VI. (one on escape), one with regulator... ...	26,600
6 Four feet culverts in approaches to bridges	
2 Locks 60 × 10, with double 10 feet waste weirs, Rs. 8,000 { Irrigation .	15,000
{ Navigation..	1,000
2 Mills (single), at Rs. 1,300 each	2,600
Carried over ...	1,08,893

	Rs.
Brought forward ...	
48 Miles of Distributary, at Rs. 1,300 per mile, for 73½ square miles of irrigation	62,400
1 First Class and one Second Class Chokee, one Assistant Engineer's and one Overseer's residence	10,675
	1,81,968
Establishment at 12½ per cent.	22,746
	2,04,714
Add 30 per cent. as before	54,590
Total	2,59,304

Buxar Branch, third part (S).

Length 11¼ miles, with 1¾ miles of escape; width at bottom 14½ feet; depth of water 2¾ feet; fall per mile 2 feet; discharge 140 cubic feet per second.

	Rs.
Land, 13 miles at Rs. 192	
Plantations	416
Roads and Fences, at Rs. 150	1,950
Excavation	25,225
Escape head, 20 feet water-way	3,250
Fall in escape tail, 25 ditto	5,500
2 Bridges, Class VII., one with regulator	14,400
4 Three feet culverts in approaches to bridges	800
2 Locks 60 × 10, at Rs. 6,500 { Irrigation	11,000
{ Navigation	2,000
2 Single Mills, at Rs. 1,300	2,600
37 Miles of Distributary, at Rs. 1,300 per mile, for 56 square miles of irrigation	48,100
1 First and one Second Class Chokee, and one Overseer's residence ...	5,425
	1,23,162
Establishment at 12½ per cent.	15,395
	1,38,557
Add 30 per cent. as before	36,949
Total	1,75,506

Buxar Branch, last part (T).

Length 18 miles, including tail escape; width at bottom 10½ feet; depth of water 2¼ feet; fall per mile 2 feet; discharge 72 cubic feet per second.

	Rs.
Land, 18 miles at Rs. 166	2,988
Plantations	498
Roads and Fences, at Rs. 150	2,700
Carried over ...	6,186

			Rs.
	Brought forward ...		6,186
Excavation			17,962
3 Falls, 2 at tail, 20 feet water-way... ..			12,000
2 Bridges, Class VIII. one with regulator ...		5,167	
4 Three feet culverts in approaches to bridges		800	
6 Metalled fords, at Rs. 150 each		900	
			6,867
2 Single Mills (one at tail fall), at Rs. 1,300			2,600
64 Miles of Distributary, at per mile Rs. 1,300, for 96 square miles			83,200
1 First and one Second Class Chokee ...			2,800
			1,31,615
	Add Establishment at 12½ per cent. ...		16,451
			1,48,066
	Add as before 30 per cent.		39,484
	Total		1,87,550

Doomraon Branch (U).

Length 13 miles, including tail escape; width at bottom 7 feet; depth of water-way 1½ feet; fall per mile 2 feet; discharge 26 cubic feet per second.

			Rs.
Land, 13 miles at Rs. 127½			1,657
Plantations			276
Roads and Fences, at Rs. 150			1,950
Excavation			7,495
2 Falls, one at tail, 10 feet water-way			4,000
3 Bridges, Class IX., one with regulator		5,465	
6 Three feet culverts in approaches to bridges ...		1,200	
3 Metalled fords at Rs. 120		360	
			7,025
2 Mills, one (at tail fall) Rs. 1,300 each ...			2,600
(No Distributary required.)			
13 Miles of canal supplied with Modules, at Rs. 400			5,200
1 Second Class Chokee			800
			31,003
	Establishment at 12½ per cent.		3,875
			34,878
	Add 30 per cent. as before		9,300
	Total		44,178

Buradhee Branch (V).

Length 13 miles, including tail escape; width 8½ feet; depth of water 2 feet; fall per mile 2 feet; discharge 48 cubic feet per second.

	Rs.
Land, 13 miles at Rs. 127½ per mile … … …	1,657
Plantations … … … … …	276
Roads and Fences at Rs. 150 … … … .	1,950
Excavation … … … … .	11,712
3 Falls, 15 feet water-way, including tail fall at … .	9,500
2 Bridges, Class IX., one with regulator … … .	3,763
4 Three feet culverts in approaches to bridges … .	800
3 Single Mills … … … … .	3,900
30 Miles of Distributary Channel, at Rs. 1,300… … ..	26,000
13 Miles of canal supplied with Modules, at Rs. 400 … ..	5,200
1 First and one Second Class Chokee … … -	2,800
	67,558
Establishment at 12½ per cent. …	8,445
	76,003
Add 30 per cent. as before … …	20,267
Total cost … Rs.	96,270

Chowsa Branch, first Part (W).

Length 6½ miles, with 7 miles of escape; width at bottom 26 feet; depth of water 4·1 feet; fall per mile 1·41 feet; discharge 395 cubic feet per second.

	Rs.
Land, 13½ miles at Rs. 255 … … … …	3,442
Plantations … … … … …	573
Roads and Fences, at Rs. 250 … … … …	3,375
Excavation … … … … …	56,855
Escape head, 40 feet water-way … … … …	7,750
1 Fall, 40 feet water-way, at tail of escape … … …	11,500
2 Bridges, one with regulator … … … …	20,900
4 Four feet culverts in approaches to bridges… … …	1,880
2 Locks (double) with double waste weirs … Irrigation …	31,000
Navigation …	59,800
2 Mills (double) at Rs. 2,200 … … … …	4,400
30 Miles of Distributary, at Rs. 1,300 per mile, for 44 square miles of Irrigation … … … … …	39,000
1 First Class Chokee, and one Overseer's residence … …	5,200
	2,45,675
Establishment at 12½ per cent. …	30,709
	2,76,384
Add 30 per cent. as before …	73,702
Total …	3,50,086

Chowsa Branch, second part (X).

Length 12½ miles, with 2 miles of escape; width at bottom 21 feet; depth of water 3½ feet; fall per mile 1·60 feet; discharge 314 cubic feet per second.

		Rs.
Land, 14½ miles at Rs. 231		3,349
Plantations		558
Roads and Fences, at Rs. 250		3,625
Excavation		35,451
Escape head, 30 feet		5,000
Tail fall for escape, 30 feet		7,500
2 Bridges, Class VI., one with regulator		17,600
4 Four feet culverts in approaches to bridges		1,880
3 Locks, single, with single waste channel { Irrigation		22,500
{ Navigation		60,000
3 Mills, double, at Rs. 2,200		6,600
54 Miles of Distributary, at Rs. 1,300 per mile, for 80 square miles of irrigation		70,200
1 First and one Second Class Chokee, and one Overseer's residence ...		5,425
		2,39,688
Establishment at 12½ per cent. ...		29,961
		2,69,649
Add 30 per cent. as before		71,906
	Total	3,41,555

Chowsa Branch, last part (Y).

Length 15 miles, including tail escape; width at bottom 18½ feet; depth of water 3½ feet; fall per mile 1·72 feet; discharge 254 cubic feet per second.

		Rs.
Land, at Rs. 231 per mile, for 15 miles		3,465
Plantations		577
Roads and fences, at Rs. 250		3,750
Excavation		27,443
3 Bridges, Class VI., one with Regulator		26,600
6 Four feet culverts in approaches to bridges		2,820
2 Locks with single chamber and waste weirs ... ... { Irrigation ...		11,000
{ Navigation	43,000	
Terminal works for descent into Kurumnassa	2,50,000	
		2,93,000
4 Mills, at Rs. 2,200 each		8,800
92 Miles of Distributary, at Rs. 1,300 per mile, for 138 square miles of area to be irrigated		1,19,600
	Carried over	4,97,055

Brought forward ...		4,97,055
2 First and 1 Second Class Chokees, 1 Assistant Engineer and 2 Overseer's residence		15,300
		5,12,355
Establishment at 12½ per cent.... ...		64,044
		5,76,399
Add 30 per cent. as before		1,53,706
Total		7,30,105

Kochus Branch (Z).

Length 13 miles, including tail escape; width at bottom 8¾ feet; depth of water 2 feet; fall per mile 2 feet; discharge 48 cubic feet per second.

		Rs.
Land for 13 miles, at Rs. 127½		1,657
Plantations...		276
Roads and Fences, at Rs. 150		1,950
Excavation		11,712
3 Falls (one at tail) 15 feet water-way		9,000
2 Bridges, Class IX., one with Regulator	3,765	
4 Three feet culverts in approaches to bridges ...	800	
4 Metalled Fords, at Rs. 150	600	
		51,65
2 Mills, at Rs. 1,300 each		2,600
30 Miles of Distributary, at Rs. 1,300 per mile		39,000
13 Miles of canal supplied with modules, at Rs. 400 per mile ...		5,200
1 First Class Chokee		2,000
		78,560
Establishment at 12½ per cent.		9,820
		88,380
Add as before 30 per cent.		23,568
Total		1,11,948

EASTERN SOANE CANAL.

Main Line (a).

Length 12 miles, escape ½ a mile; width at bottom 52 feet; depth of water 6½ feet; fall per mile 0·94 foot; discharge 1,144 cubic feet per second.

		Rs.
Land, 12½ miles at Rs. 768		9,600
Plantations		1,600
Roads and Fences, at Rs. 400		5,000
Carried over ...		16,200

		Rs.
Brought forward ...		16,200
Excavation		4,46,709
Drainage works as detailed in Report		1,55,795
3 Bridges deep cutting	70,500	
4 Ordinary bridges	64,000	
		1,34,500
Escape head of 60 feet water-way		12,500
3 Falls, 80 feet water-way, on escape		81,000
10 Miles of distributary for watering the low land on the Soane bank, at Rs. 1,300		13,000
1 First Class and 2 Second Class Chokees, 1 Assistant Engineer and 2 Overseers' residences		15,300
		8,75,004
Establishment at 12½ per cent.		1,09,375
		9,84,379
Add 30 per cent. as before		2,62,501
Total ...		12,46,880

Patna Branch, first part (b).

Length 8 miles, with ½ mile escape; width at bottom 38½ feet; depth of water 5½ feet; fall per mile 1·11 feet; discharge 735 cubic feet per second.

	Rs.	Rs.
Land for 8½ miles canal, at Rs. 422	7,103	
Ditto for Executive Engineer's Head Quarters ...	192	
Ditto for 3 lock channels	3,456	
		10,751
Plantations		1,182
Roads and fences, at Rs. 250		2,125
Excavation		57,852
2½ Bridges, Class III., (one for Grand Trunk Road) and one with Regulator		39,200
4 Four feet culverts in approaches to bridges		1,880
Escape channel head, 50 feet water-way		11,000
3 Falls on escape, 50 feet water-way		46,500
8 Falls with double locks and lock channels { Irrigation ...		69,000
{ Navigation ...		1,36,800
3 Sets of double mills, at Rs. 2,200		6,600
22 Miles of distributaries, at Rs. 1,300		28,600
1 First Class Chokee, and 2 Overseers' residences, also Head Quarters of an Executive Engineer, with Office for 2 Clerks and workshops		33,000
		4,40,998
Establishment at 12½ per cent.		55,125
		4,96,123
Add 30 per cent. as before		1,32,299
Total		6,28,422

Patna Branch, second part (c).

Length 14 miles, with escape ½ a mile; width at bottom 34½ feet; depth of water 4⅞ feet; fall per mile 1·18 feet; discharge 659 cubic feet per second.

		Rs.
Land, 14½ miles, Rs. 282 per mile		4,089
Plantations		681
Roads and fences, at Rs. 250		3,625
Excavation		58,618
Escape head, 40 feet water-way		7,750
2 Falls on escape, 50 feet water-way		31,000
2 Bridges, Class IV. (one with Regulator)		23,370
4 Four feet culverts in approaches		1,880
3 Falls with locks (double), with double waste weirs and channels, at Rs. 64,400	Irrigation	60,000
	Navigation	1,33,200
3 Sets of double Mills, at Rs. 2,200		6,600
50 Miles of distributaries, at Rs. 1,300 per mile, for 74 square miles of irrigation		65,000
1 First Class and 3 Second Class Chokees, and 2 Overseer's residences		10,450
		4,06,263
Establishment at 12½ per cent....		50,783
		4,57,046
Add 30 per cent. as above		1,21,878
Total cost ... Rs.		5,78,924

Patna Branch, third part (d).

Length 26¾ miles, with ¾ mile of escape; width at bottom 29½ feet; depth of water 4½ feet; fall per mile 1¼ feet; discharge 424 cubic feet per second.

		Rs.
Land, 27½ miles, at Rs. 282 per mile		7,755
Plantations		1,292
Roads and fences, at Rs. 250		6,875
Excavation		95,851
Escape head, 40 feet water-way		7,750
3 Falls on escape, 40 feet water-way		34,500
5 Bridges, Class IV. (one with Regulator)		53,370
10 Four feet culverts in approaches		4,700
4 Double locks with double waste channels	Irrigation	62,000
	Navigation	1,19,600
4 Double Mills, at Rs. 2,200....		8,800
96 Miles of distributary, at Rs. 1,300 per mile for 144 square miles of irrigation		1,24,800
Carried over ...		5,26,293

	Rs.
Brought forward ...	5,26,293
2 First and 4 Second Class Chokees, 1 Assistant Engineer, and 2 Overseers' residences	17,700
	5,43,993
Establishment at 12½ per cent.	67,999
	6,11,992
Add 30 per cent. as before	1,63,197
Total cost ... Rs.	7,75,189

Patna Branch, fourth part (e).

Length 9¾ miles, with ¾ mile of escape; width at bottom 26 feet; depth of water 4 feet; fall per mile 1·4 feet; discharge 391 cubic feet per second.

	Rs.
Land, 11½ miles, at Rs. 255 per mile	2,932
Plantations	488
Roads and fences, at Rs. 250	2,875
Excavation	29,266
Escape head, 30 feet water-way	6,500
3 Falls on escape, 40 feet water-way	34,500
2 Bridges (Class V)., one with Regulator...	20,915
4 Four feet culverts in approaches	1,880
2 Locks with double chambers and waste weirs ... ... { Irrigation	31,000
{ Navigation	58,200
2 Sets of double mills, at Rs. 2,200	4,400
30 Miles of distributaries, at Rs. 1,300 per mile, for 45 square miles of irrigation	39,000
1 First Class and 1 Second Class Chokee and 1 Overseer's residence	5,425
	2,37,381
Establishment at 12½ per cent....	29,672
	2,67,053
Add 30 per cent. as before	71,214
Total cost ... Rs.	3,38,267

Patna Branch, last part (f).

Length 27 miles to terminus on Ganges; width at bottom 18 feet; depth of water 3½ feet; fall per mile 1·78 feet; discharge 234 cubic feet per second.

	Rs.
Land, 27 miles, at Rs. 231 per mile	6,237
Plantations	1,039
Carried over	7,276

	Rs.
Brought forward ...	7,276
Roads and fences, at Rs. 250	6,750
Excavation	74,657
12 Bridges, Class VI., one with Regulator (an extra number is given for communications near the City of Patna, and to allow of some being made wider)	98,620
24 Four feet culverts in approaches	11,280
Terminal works	3,50,000
2 sets of Mills at ditto, at Rs. 2,200	4,400
75 Miles of Rajbuhas, at Rs. 1,300 per mile, for 112 square miles of irrigation	97,500
2 First Class and 2 Second Class Chokees, 1 Assistant Engineer and 2 Overseers' residences	16,100
	6,66,583
Establishment at 12½ per cent....	83,323
	7,49,906
Add 30 per cent. as before ...	1,99,974
Total cost ... Rs.	9,49,880

Jakhowra Branch (*g*).

Length, including tail escape, 24½ miles; width at bottom 9 feet; depth of water 2 feet; fall per mile 2 feet; discharge 54 cubic feet per second.

	Rs.	Rs.
Land, at Rs. 127½ per mile		3,124
Plantations		521
Roads and fences, at Rs. 150		3,675
Excavation		22,411
7 Falls, including 3 near tail of 15 feet water-way ...		21,000
3½ Bridges, Class IX. (one district road), one with Regulator	5,890	
6 Three feet culverts in approaches	1,200	
6 Metalled fords, at Rs. 150 each	900	
		7,990
4 Mills, at Rs. 1,300 each		5,200
48 Miles of distributary, at Rs. 1,300 per mile,, for 71 square miles of irrigation or deducting the length of canal 24		62,400
24 Miles of canal supplied with modules, at Rs. 400 per mile		9,600
1 First and 2 Second Class Chokees		3,600
		1,39,521
Establishment at 12½ per cent.		17,440
		1,56,961
Add 30 per cent. as before		41,856
Total cost ...Rs.		1,98,817

Kojhassa Branch (h).

Length 27 miles, including tail escape; width at bottom 10½ feet; depth of water 2½ feet; fall per mile 2 feet; discharge 72 cubic feet per second.

		Rs.
Land, Rs. 153 per mile		4,131
Plantations		688
Roads and fences, at Rs. 150		4,050
Excavation		
5 Falls (two at tail) 15 feet water-way		15,000
	Rs.	
3 Bridges, Class VIII. (one with Regulator) ...	7,467	
6 Three feet culverts in approaches	1,200	
8 Metalled fords, at Rs. 150	1,200	
		9,867
4 Mills (single), at Rs. 1,300...		5,200
64 Miles of distributary, at Rs. 1,300 per mile for 97 square miles of irrigation		83,200
1 First Class and 2 Second Class Chokees		3,600
		1,52,680
Establishment at 12½ per cent.		19,085
		1,71,765
Add 30 per cent. as before ...		45,804
cost ... Rs.		2,17,569

Paleegunj Branch (i).

Length 14 miles; width at bottom 7 feet; depth of water 1¾ feet; fall per mile 2 feet; discharge 33 cubic feet per second.

		Rs.
Land, 14 miles, at Rs. 127½ per mile		1,785
Plantations		297
Roads and fences, at Rs. 150		2,100
Excavation		8,072
4 Falls, 15 feet water-way (two at tail)		12,000
	Rs.	
1 Bridge, Class IX., at head, with Regulator ...	2,065	
2 Three feet culverts in approaches	400	
3 Metalled fords, at 120 feet	360	
		2,825
3 Mills, at Rs. 1,300		3,900
30 Miles of distributary, at Rs. 1,300 per mile, for 45 square miles of irrigation, or, deducting the length of canal, 14 miles		39,000
Carried over		69,979

		Rs.
	Brought forward	69,979
14 Miles of canal supplied with modules, at Rs. 400 per mile		5,600
1 First and 1 Second Class Chokee		2,800
...		78,379
Establishment at 12½ per cent.		9,797
...		88,176
Add 30 per cent. as before		23,513
	Total cost ... Rs.	1,11,689

Dinapoor Branch (j).

Length 20 miles, width at bottom 14 feet; depth of water 2¾ feet; fall per mile 2 feet; discharge 124 cubic feet per second.

	Rs.	Rs.
Land, 20 miles at Rs. 192 per mile		3,840
Plantations		640
Roads and fences		3,000
Excavation		38,033
3 Falls at tail, of 25 feet water-way		16,500
8 Bridges, Class VII., (see remark to last part of Patna Branch) one with Regulator		50,400
16 Four feet culverts in approaches		7,520
2 Mills, at Rs. 1,300		2,600
110 Miles of distributary at Rs. 1,300 per mile for 165 square miles of irrigation		1,43,000
1 First and 2 Second Class Chokee, and 1 Overseer's residence		6,225
...		2,71,758
Establishment at 12½ per cent.		33,970
...		3,05,728
Add 30 per cent. as before		81,527
Total cost ...Rs.		3,87,255

Tikaree Branch, first part (k).

Length 10 miles, with one mile of escape; width at bottom 26 feet; depth of water 4 feet; fall per mile 1·40 feet; discharge 400 cubic feet per second.

		Rs.
Land, 11 miles, at Rs. 255 per mile	2,805	
Ditto Executive Engineer, Head Quarters, 32 beeghas ...	192	
		2,997
	Carried over	2,997

		Rs.	Rs.
	Brought forward ...	...	2,997
Plantations		...	499
Roads and fences, at Rs. 250		...	2,750
Excavation		...	62,508
Passage of Poonpoon		2,00,000	
Ditto of Bootana		6,00,000	
Ditto of two small tributaries to Poonpoon ...		50,000	
			8,50,000
2 Falls of 40 feet water-way for escape		...	23,000
3 Bridges, Class V., one with Regulator		...	29,915
6 Four feet culverts in approaches		...	2,820
20 Miles of distributary, at Rs. 1,300 per mile, for 30 miles of irrigated area			26,000
1 First Class and 1 Second Class Chokee, and 3 Overseers' residences		11,275	
Executive Engineer's residence, with Office, 2 Clerks' residences and work-shop		25,750	
			37,025
			10,44,014
	Establishment at 12½ per cent.	...	1,30,501
			11,74,515
	Add 30 per cent. as before	...	3,13,205
		ost ... Rs.	14,87,720

Tikaree Branch, second part (*l*).

Length 5 miles (no escape); width at bottom 23 feet; depth of water 3¾ feet; fall per mile 1·51 feet; discharge 361 cubic feet per second.

		Rs.
Land, 5 miles, at Rs. 255 per mile		1,275
Plantations		212
Roads and fences, at Rs. 250		1,250
Excavation		22,453
Passage of the Uddree		90,000
2½ Bridges, Class V., one with Regulator and one on Grand Trunk Road...		29,415
4 Four feet culverts in approaches		1,880
6 Miles of distributary, at Rs. 1,300		7,800
1 Second Class Chokee, and 1 Overseer's residence		3,425
		1,57,710
	Establishment at 12½ per cent.	19,713
		1,77,423
	Add 30 per cent. as before	47,313
	Total cost ... Rs.	2,24,736

Tikaree Branch, third part (m).

Length 11 miles, escape 1 mile; width at bottom 20 feet; depth of water 3½ feet; discharge 287 cubic feet per second.

	Rs.
Land, 12 miles, at Rs. 231 per mile	2,772
Plantations	462
Roads and fences, at Rs. 250	3,000
Excavation	34,062
Passages of the Tikaree and Mudar	1,26,000
Escape head 30 feet water-way	5,000
2 Falls, 30 feet water-way on escape	15,000
4 Bridges, Class VI., one with Regulator	34,620
8 Four feet culverts in approaches	3,760
12 Miles of distributary, at Rs. 1,300 per mile, for 18 square miles of irrigation	15,700
1 First and 1 Second Class Chokee, and 1 Assistant Engineer's and 2 Overseers' residences ...	13,300
	2,53,676
Establishment at 12½ per cent.	31,709
	2,85,385
Add 30 per cent. as before	76,103
Total cost ... Rs.	3,61,488

Tikaree Branch, fourth part (n).

Length 8 miles, (no escape; width at bottom 18½ feet; depth of water 3½ feet; fall per mile 1·74 feet; discharge 259 cubic feet per second.

	Rs.
Land, 8 miles, at Rs. 231 per mile	1,848
Plantations	308
Roads and fences, at Rs. 250	2,000
Excavation	21,648
Passage of the Dhawa	36,000
3 Bridges, Class VI., one with Regulator	26,620
6 Four feet culverts in approaches	2,820
10 Miles of distributary, at Rs. 1,300	13,000
1 Second Class Chokee and 1 Overseer's residence	3,425
	1,07,664
Establishment at 12½ per cent.	13,458
	1,21,122
Add 30 per cent. as before	32,299
Total cost ... Rs.	1,53,421

Tikaree Branch, fifth part (o).

Length 5 miles, (no escape); width at bottom 17 feet; depth of water 3½ feet; fall per mile 1·85 feet; discharge 219 cubic feet per second.

	Rs.
Land, 5 miles, at Rs. 231 per mile	1,155
Plantations	192
Roads and fences, at Rs. 250	1,250
Excavation	10,672
2 Bridges, Class VI. (one with Regulator)	18,620
4 Four feet culverts in approaches...	1,880
19 Miles of distributary, at Rs. 1,300 per mile, for 27½ square miles of irrigation	24,700
1 Second Class Chokee	800
	59,269
Establishment at 12½ per cent.	7,408
	66,677
Add 30 per cent. as before	17,781
Total cost ... Rs.	84,458

Tikaree Branch, sixth part (p).

Length 4 miles, with 2 miles of escape; width at bottom 14½ feet; depth of water 2¾ feet; fall per mile 2 feet; discharge 134 cubic feet per second.

	Rs.	Rs.
Land, 6 miles, at Rs. 192 per mile		1,152
Plantations		192
Roads and fences, at Rs. 150		900
Excavation		9,381
Passage of the Neara River	15,000	
Head of escape, 20 feet water-way	2,200	
2 Falls for escape, 20 feet water-way	8,000	
		25,200
2 Bridges, Class VII. (one with Regulator)		14,410
4 Three feet culverts in approaches		800
10 Miles of distributary, at Rs. 1,300 per mile, for 14 square miles of irrigation		13,000
1 First Class Chokee, 1 Assistant Engineer's residence... ...		7,250
		72,285
Establishment at 12½ per cent.		9,035
		81,320
Add 30 per cent. as before		21,685
Total cost ... Rs.		1,03,005

Tikaree Branch, last part (q).

Length 24 miles to tail escape; width at bottom 10 feet, depth of water $2\frac{1}{2}$ feet; fall per mile 2 feet; discharge 64 cubic feet per second :—

	Rs.	Rs.
Land, 24 miles, at Rs. 166 per mile		3,984
Plantations		664
Roads and fences, at Rs. 150		3,600
Excavation		30,337
4 Falls (2 at tail escape) 15 feet water-way ...	12,000	
4 Locks, at Rs. 6,500... Irrigation	16,000	28,000
Navigation	10,000	10,000
5 Sets of mills, at Rs. 1,300		6,500
2 Bridges, Class VIII. (one with Regulator)		5,167
4 Three feet culverts in approaches		800
39 Miles of distributary, at Rs. 1,300 per mile, for 85 miles of irrigation allowing for the canal		50,700
24 Miles of Canal supplied with modules, at Rs. 400		9,600
1 First and 2 Second Class Chowkees and 1 Overseer's residence		6,225
		1,55,577
Establishment at $12\frac{1}{2}$ per cent.		19,447
		1,75,024
Add 30 per cent. as before		46,673
Total cost	Rs.	2,21,697

Jummoor Branch (r).

Length $6\frac{1}{2}$ miles; width at bottom 5 feet; depth of water $1\frac{1}{2}$ feet; fall per mile 2 feet; discharge 15 cubic feet per second.

	Rs.
Land, at Rs. 102 per mile	663
Plantations	110
Roads and fences, at Rs. 150	975
Excavation	3,171
2 Falls of 7 feet water-way at tail 3 Falls in canal ditto ...	5,000
3 Mills at Rs. 1,300	3,900
1 Bridge, Class X, with Regulator	1,599
(No distributary required.)	
Modules for $6\frac{1}{2}$ miles of canal, at Rs. 400	2,600
	18,015
Establishment at $12\frac{1}{2}$ per cent. ...	2,252
	20,267
Add 30 per cent. as before ...	5,404
Total cost ... Rs.	25,671

Khurona Branch (s).

Length 16 miles to tail escape; width at bottom 10½ feet; depth of water 2¼ feet; fall per mile 2 feet; discharge 71 cubic feet per second.

	Rs.
Land, 16 miles, at Rs. 166 per mile	2,656
Plantations	443
Roads and fences, at Rs. 150	2,400
Excavation	1[illegible]45
7 Falls (2 at tail escape), 20 feet water-way	28,000
1 Bridge, Class VIII., with Regulator	2,867
2 Three feet culverts in approaches	400
5 Sets of mills, at Rs. 1,300	6,500
48 Miles of distributary, at Rs. 1,300 per mile, for 94½ square miles of area, allowing for the 16 miles of canal ...	62,400
16 Miles of canal supplied with modules, at Rs. 400	6,400
1 First and 1 Second Class Chokee	2,800
	1,30,611
Establishment at 12½ per cent.	16,326
	1,46,937
Add 30 per cent. as before	39,183
Total cost, ... Rs.	1,86,120

Achore Branch (t).

Length 5½ miles; width at bottom 5 feet; depth of water 1¼ feet; fall per mile 2 feet; discharge 15 cubic feet per second.

	Rs.
Land, 5½ miles, at Rs. 102 per mile	561
Plantations	93
Roads and fences, at Rs. 150 ...	825
Excavation	2,683
2 Falls, 7 feet water-way at tail; 2 Ditto ditto on canal	4,000
2 Mills, at Rs. 1,300	2,600
1 Bridge, Class X., with Regulator	1,597
2 Three feet culverts in approaches	400
(No distributary needed.)	
5½ Miles of canal supplied with modules, at Rs. 400 per mile	2,200
	14,959
Establishment at 12½ per cent. ...	1,869
	16,828
Add 30 per cent. as before ...	4,488
Total cost ... Rs.	21,316

Dadur Branch (*u*).

Length 12 miles; width at bottom 7 feet; depth of water 1¾ feet; fall per mile 2 feet; discharge 33 feet per second.

	Rs.
Land, 12 miles, at Rs. 127½ per mile	1,530
Plantations	255
Roads and fences, at Rs. 150	1,800
Excavation	6,918
2 Falls, 10 feet water-way at tail 4 Ditto on canal ... }	12,000
1 Bridge, Class IX., with Regulator	2,065
2 Three feet culverts in approaches	400
4 Mills, at Rs. 1,300	5,200
20 Miles of distributary, at Rs. 1,300 per mile, for 44 square miles of irrigation allowing for the length of canal	26,000
12 Miles of canal provided with modules, at Rs. 400	4,800
1 First and 1 Second Class Chokee, and 1 Overseer's residence ...	5,425
	66,393
Establishment at 12½ per cent....	8,299
	74,692
Add 30 per cent. as before	19,917
Total cost ... Rs.	94,609

Humeednuggur Branch (*v*).

Length 15½ miles; width at bottom 10 feet; depth of water 2¼ feet; fall per mile 2 feet; discharge 64 cubic feet per second.

	Rs.
Land, 15½ miles, at Rs. 166 per mile	2,573
Plantations	429
Roads and fences, at Rs. 150 ...	2,325
Excavation	15,038
2 Falls, 15 feet water-way at tail 5 Ditto on canal ... ... }	21,000
1 Bridge, Class VIII., with Regulator	2,867
2 Three feet culverts in approaches	400
5 Mills, at Rs. 1,300	6,500
Miles of distributary, at Rs. 1,300 per mile, for 85 square miles of irrigation, allowing for length of canal ...	54,600
Carried over...	1,05,732

Brought forward... -	
15½ Miles of canal supplied with modules, at Rs. 400	6,200
1 First and 1 Second Class Chokee, and 1 Overseer's residence	5,425
	1,17,357
Establishment at 12½ per cent.	14,669
	1,52,026
Add 30 per cent. as before	35,209
Total cost ... Rs.	1,67,233

Kutangee Branch (*w*).

Length 15 miles; width at bottom 9½ feet; depth of water 2 feet; fall per mile 2 feet; discharge 58 cubic feet per second.

	Rs.
Land, 15 miles, at Rs. 166 per mile	2,490
Plantations	415
Roads and fences, at Rs. 150	2,250
Excavation	14,137
2 Falls, 15 feet water-way at tail } 8 Falls on canal ... }	30,000
1 Bridge, Class VIII., with Regulator	2,867
2 Three feet culverts in approaches	400
4 Mills, at Rs. 1,300	5,200
42 Miles of distributary, at Rs. 1,300 per mile for 76½ square miles of area to be irrigated, allowing 15 miles per length of canal...	46,800
15 Miles of canal supplied with modules, at Rs. 400	6,000
1 First and 1 Second Class Chokee	2,800
	1,13,359
Establishment at 12½ per cent.	14,169
	1,27,528
Add 30 per cent. as before	34,008
Total cost ... Rs.	1,61,536

NAVIGATION LINES.

I. Line from the Dinapore Branch Head to Patna.

Length 27 miles; width at bottom 20 feet; depth of water 3½ feet; fall per mile 1 inch; discharge theoretically 63 feet per second.

	Rs.
Land, at Rs. 231 per mile	6,237
Plantations	1,039
Roads and fences, at Rs. 250 per mile	6,750
Excavation	52,096
4 Single locks 120 × 16 with waste weir, one at head, at Rs. 27,500	1,10,000
9 Bridges, Class VI., at Rs. 8,000	72,000
1 First and 3 Second Class Chokees, and 1 Overseer's residence	7,025
	2,55,147
Establishment at 12½ per cent. ...	31,893
	2,87,040
30 per cent. added as before ...	76,544
Total cost	3,63,584

II. Line from the head of the Nansaugor Branch to Arrah.

Length 20 miles, other dimensions as above.	Rs.
Land, at Rs. 231 per mile	4,620
Plantations	770
Roads and fences, at Rs. 250 per mile	5,000
Excavation	38,586
7 Single locks 120 x 16, at Rs. 27,500	1,92,500
3 Bridges, Class VI., at Rs. 8,000	24,000
1 First and 2 Second Class Chokees	3,600
	2,69,076
Establishment at 12½ per cent.	33,634
	3,02,710
30 per cent. added as before	80,723
Total cost	3,83,433

III. Line from the Roohus Branch Head to the Kurumnassa.

Length 27 miles, other dimensions as before—	Rs.
Land at Rs. 231 per mile	6,237
Plantations	1,039
Roads and fences, at Rs. 250	6,750
Excavation	52,096
10 Locks single 120 × 16, at Rs. 27,500	2,75,000
2 Bridges, Class VI., at Rs. 8,000	16,000
1 First and 4 Second Class Chokees, and 2 Overseer's residence ...	10,450
	3,67,572
Establishment 12½ per cent.	45,946
	4,13,518
Add 30 per cent. as before	1,10,271
Total cost	5,23 789

IV. Line from Kuromodeea to the Head of the Benares Main Navigable Line.

Length 15 miles, other dimensions as before—	Rs.
Land 15 miles, at Rs. 231	3,465
Plantations	577
Roads and Fences, at Rs. 250	3,750
Excavation	42,577
7 Locks as above	1,92,500
1 Bridge	8,000
1 First and 2 Second Class Chokees	3,600
	2,54,469
Establishment at 12½ per cent. ...	31,808
	2,86,277
Add 30 per cent. as before ...	76,341
Total cost	3,62,618

V. *Main Navigation line to Benares.*

Length 56 miles; width at bottom 25 feet; depth of water 5 feet; fall per mile 4 inches; discharge, theoretical, 247 cubic feet per second.

	Rs.
Land, at Rs. 225 per mile	14,280
Plantations	2,380
Roads and Fences, at Rs. 250	14,000
Excavation	3,10,464
4 Locks, double, with single waste weir, at Rs. 38,000	1,52,000
Passage of the Kordra 150, Doorgowtee 200, Kukur 40, Soora 60, Koora 60, Gonhooa 40, and Kurumnassa 250; total 800 running feet of water-way, at Rs. 800	6,40,000
16 Bridges, 1st class, at Rs. 9,000	1,44,000
Descent into the Ganges	2,50,000
8 Mills, at Rs. 2,200	17,600
5 First Class and 6 Second Class Chokees, 1 Assistant Engineer's, and 8 Overseer's residences	41,050
	15,85,774
Add Establishment at 12½ per cent.	1,98,222
	17,83,996
Add 30 per cent. as before	4,75,732
Total cost ...	22,59,728

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